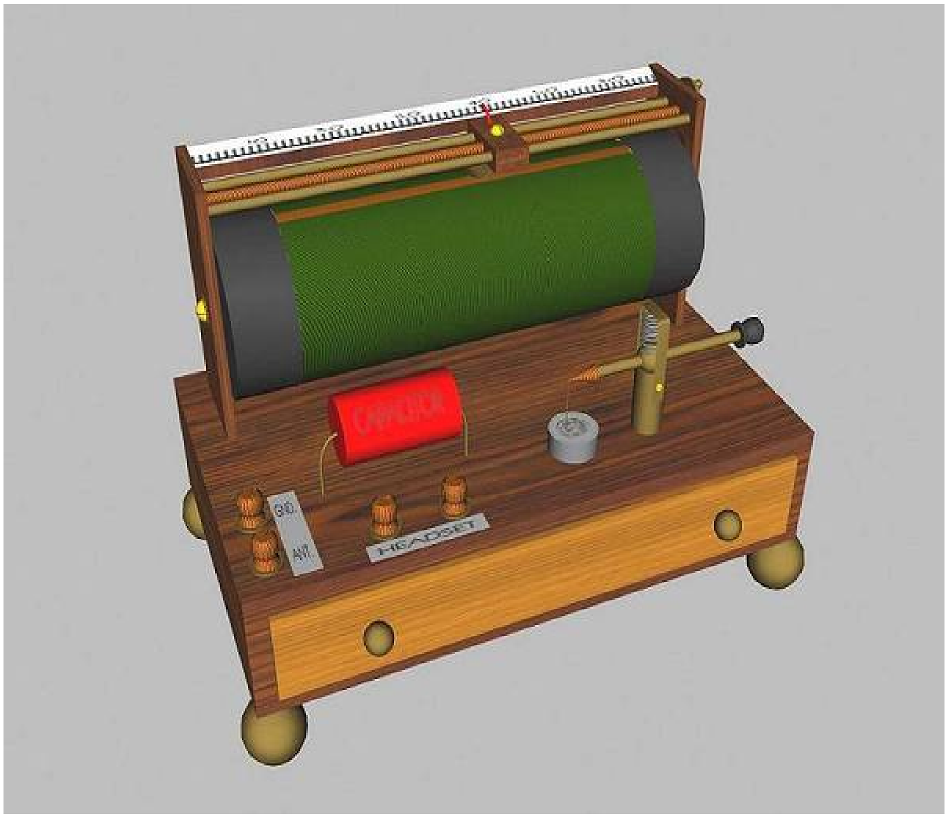
undefined

Crystal Radio



This was the second version designed in CAD. I added the drawer and a log scale to the radio. It is not build to any scale.... just a "rough sketch" to try different configurations.

Rather than use the typical antenna tuner, which is a brass strip on a pivot, I decided to run my tuner contact on two brass rods, with a crank and screw to drive it across the antenna coil.

The cat wisker rod is 1/8" brass, with a solid brass ball I drilled through, then soldered to the rod. I did away with the CAD drawing's bail and spring arrangement, and in practice found a simple formed spring was simplier.

Here is the radio apart and stripped in preparation for finishing. You can see the turned cherry posts for supporting the capacitor in the drawer. To the left of them are the knobs for the tuner crank and the wisker rod.

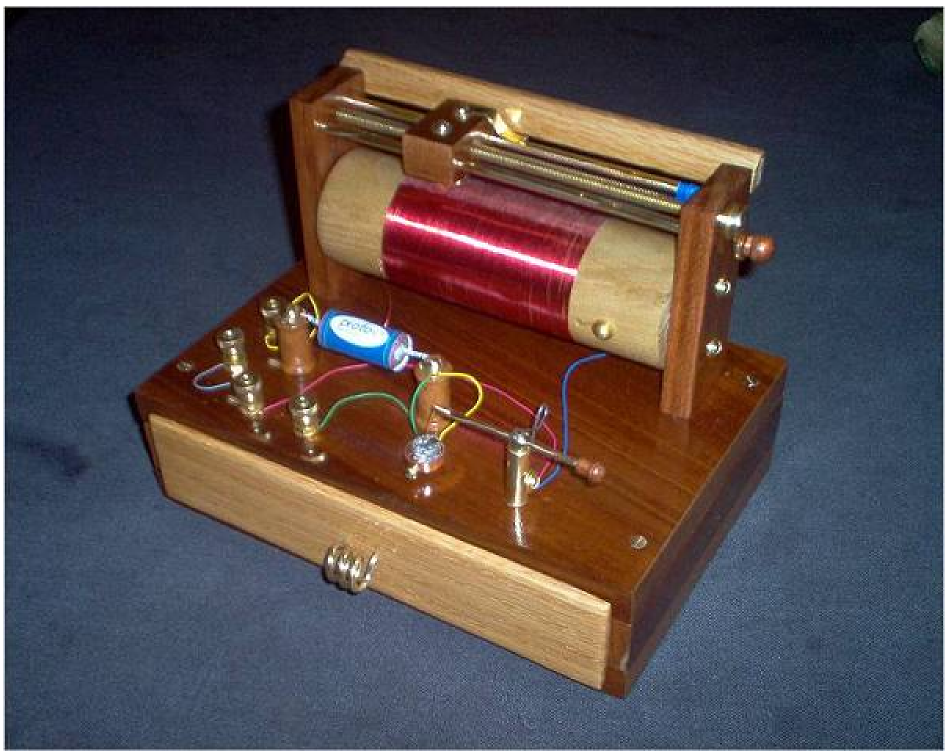
I plan on finding either real or good fake bone to make a log scale for the white oak "bar"... so finding the proper place on the coil for a given antenna will be easier.

On the threaded rod can be seen the brass crank, minus it's knob. The crank is cut from 3/16" brass plate, threaded 1/4-20, then soldered to the rod. There is a nut in the dark wood tuning block, which this rod threads into. So... turning the crank moves the rod: 20 turns=one inch.

I was lucky to find an classic (from the 40's) high impedence earphone which fits in this drawer... head piece, cloth wire, connectors and all!

The radio almost done. It is all shellacked, and I polished all the brass with White Diamond on my Unimat. I still need to add feet, a log scale to the oak bar above the antenna tuner, and make a plexi case for it. I also will make up an antenna, ground wire with small stake, and instruction booklet to keep in the drawer.

And it works! In the early evening I was getting a local station, WLNA, Peekskill 1420. I also got two other stations I could not identify... they are pretty faint. Imagine my surprise when I tried it again after dark, and heard Arabic... loud! So I played around, and heard Chinese. It was in Chinese, with Chinese music... I did not know, nor think it was possible, that these radio picked up shortwave. I listened for a bit, and sure enough the announcer said in English: "CRI", for China Radio International. Then more Chinese, then "...cri.com...". So unless they use a repeater closer to me, I just heard the other side of the world on this job.



This was with a 100' long wire antenna, and a 1/4" copper ground stake for a ground. I later heard French, two different Spanish stations, and various other faint and garbled stations. I had no idea this was even possible on a crystal set. I've since read that it is common to receive shortwave on such a setup... and that time of day is a major factor in what you will recieve when you have no tuning capacitor. I tried again just after dark and heard French, two Asian, two Spanish and one German station. I also could clearly hear (and understand!) an American evangalist... I think he was one from Indiana.

I've left room on the chassis for a tuning capacitor I have been designing. Rather than rotating, it will mesh rectangular sheets of aluminum flashing on a flat plane. The sheets will stand up, and be meshed with a screw crank similar to the crank for the antenna tuner. It will fit just behind the crystal/cat whisker setup. I only need to compute the area for the plates, then I can make and experimental version to test it out on the set.

The Trimm Featherweight headphone I am using is the loudest of all the ones I have around. But the thing is, it only measures about 300 ohms. I've read that 2000 ohms is what you are looking for in crystal earphones... and so I was trying other sets. I have a 1,200 ohm set, two sets which read 2000 and 3800 ohms. But non of them are as loud as the 300 ohm Trimm.

Still, the sound is very low, as built. To isolate the reasons, I thought I would swap out the different components. First I replaced the cap I made with a factory .002 Mfd one. This did not change the performance at all, so the theory I made a "leaky" cap was out. I sent for some 1N34 germanium diodes, and clipped one to the cat whisker and crystal cup, with the whisker raised. The sound was suddenly loud and clear! This test exonerated my antenna, coil, slide switch, ground, whisker post and rod, wiring, and so on. I realize now that the natural galena crystal is just way less "sensitive" than the

factory diode. Since I have no experience in these radios I cannot know how sensitive a different galena crystal might be... but now that I know the crystal is the performance culprit, I will get a chunk of galena and try other pieces.

The local station, WLNA, comes in... but weak, like I said (China comes in louder). As an experiment I drove to a park (before I had the germanium diodes) within a half-mile of the antenna. I drove about 2' of brass rod in the ground, and stretched a 30' antenna up to a tree. I tied it to the tree with string to insulate it. For the life of me, I could not get a sound! At home, the station came in weak. Within spitting distance of the antenna, not a peep. Go figure.

I finally, four years later (2011), got around to finishing the radio. I made a glass cover for it, and added copper plated brass feet. I did not turn the feet, they are drawer pulls.

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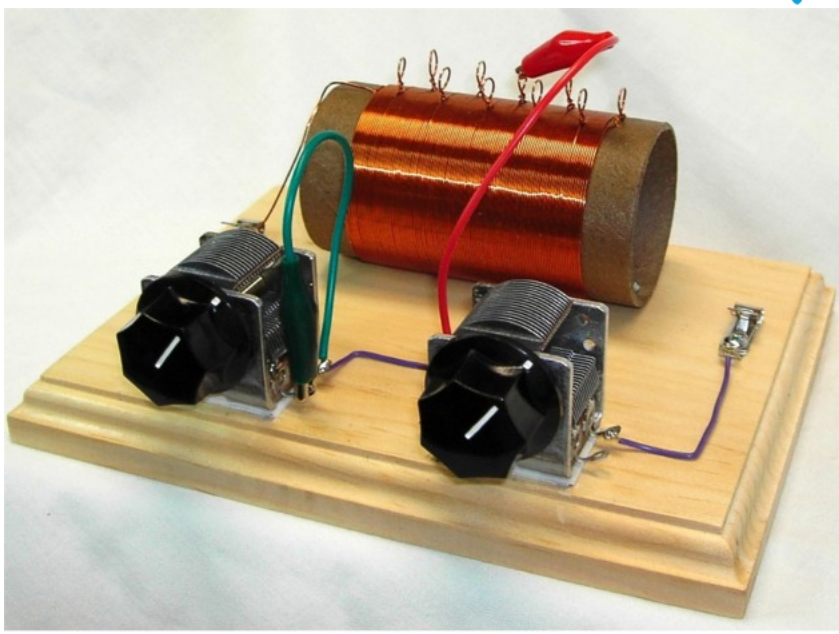
the Chum Bucket

Radiokit.su



Alfred P. Morgan was a prolific early writer of books on the subjects of electricity, wireless telegraphy, and radio. His works were written for young people and the average man who wasn't an expert in mathematics and physics. His book, "THE BOY ELECTRICIAN", originally published in 1913 and many printings after, taught many a youngster how to make crystal radios, wireless transmitters, antennas, and all kinds of electrical experiments. Many young people who built Morgan's projects later became engineers and scientists. This great little antenna tuner is named after Alfred P. Morgan for his influence on the lives and careers of many people. In the early days of wireless, very low frequency, very long wavelength signals were used. These extremely long wavelengths required exceptionally long antennas in order to be resonant. It was impractical to have antennas that were thousands of feet long, so early designers found a way around this problem by using "loading coils" to artificially lengthen their antennas. These loading coils were adjustable coils of wire, or Inductors. A variable capacitor was often added in parallel with the loading coils to "fine tune" their shorter antennas to the resonance of a much longer antenna. During the 1920s, amateur radio experimenters discovered that shorter wavelength signals would "skip" off the Ionosphere and thus allowed very long distance communications using low transmitter power on the "Short Wave" bands. Many antennas were too long to resonate at these shorter wavelengths. The designers found that a variable capacitor connected in-series with the antenna allowed it to be tuned to resonance at the higher frequency short wavelengths. Because we like to operate on multiple frequencies, loading coils with parallel-connected variable capacitors and series capacitors were combined into one circuit and were then called "Antenna Tuners." The Morgan Crystal Radio Antenna Tuner works to tune random wire antennas from approximately fifty feet and longer for crystal sets and more complex radios on the A.M. Broadcast Band, Short Wave and Amateur Bands up to about 30 MHZ. By tuning your antenna to resonance, it will transfer the energy from the received radio wave to your set more efficiently. This will result in a louder signal that will allow weaker "DX" stations to be heard that were not audible before. This antenna tuner can also be used to increase the selectivity of simple receivers. This feature helps to separate the faint DX stations from the strong locals. Building this antenna tuner is accomplished using simple assembly techniques and high quality parts. The air variable capacitors are the same fine American-made units that we use on our Armstrong One Tube Radio Kits, Dunwoody High Performance Crystal Radio Kits, and Bucher Crystal Radio QRM Rejectors. This kit is based on our ELECTRONICS HANDBOOK Magazine article, "How To Build And Use A Crystal Set Antenna Tuner", reprints of which are available in our "Literature" Link. This is an improved version of that antenna tuner. Clip-leads are used for the coil tap connections and for shorting the series capacitor when it is not in use. The clip-leads simplify construction and eliminate the signal-robbing losses that result from the use of a rotary switch and its many leads. Very good results can be expected with this antenna tuner. It has been used successfully used with our Dunwoody High Performance Crystal Radio and with our Armstrong One Tube Radio. It also works well with our Cornell WW-II Foxhole Radio and our Pickard Crystal Radio. It has been used with antique radios and commercial communications receivers. In addition to this, it can be used with low power "QRP" amateur radio transmitters to match the transmitter's output impedance to an end-fed wire antenna. One customer says, "This antenna tuner will increase the number of A.M. DX stations received on a one-tube set ten-fold!" Highest quality parts are used throughout. The pre-drilled routed baseboard is made for us by TOLEWOOD.COM from clear furniture grade pine that can be stained for an attractive vintage look. The pre-punched coil form is made from the same heavy cardboard shipping tube as our Dunwoody High Performance Crystal Set. Quality black Bakelite knobs contribute to the vintage appearance. Nickel-plated brass fahnestock clips are used for the input and output connections. All parts, screws, clip-leads, and wire are included in this fine quality kit. The easy-to-understand instructions were designed for beginners, however the coil winding is at a level of difficulty for more experienced builders. Soldering is required.

Complete kit including all parts and easy to follow instructions:

Source: http://www.xtalman.com/kits.html

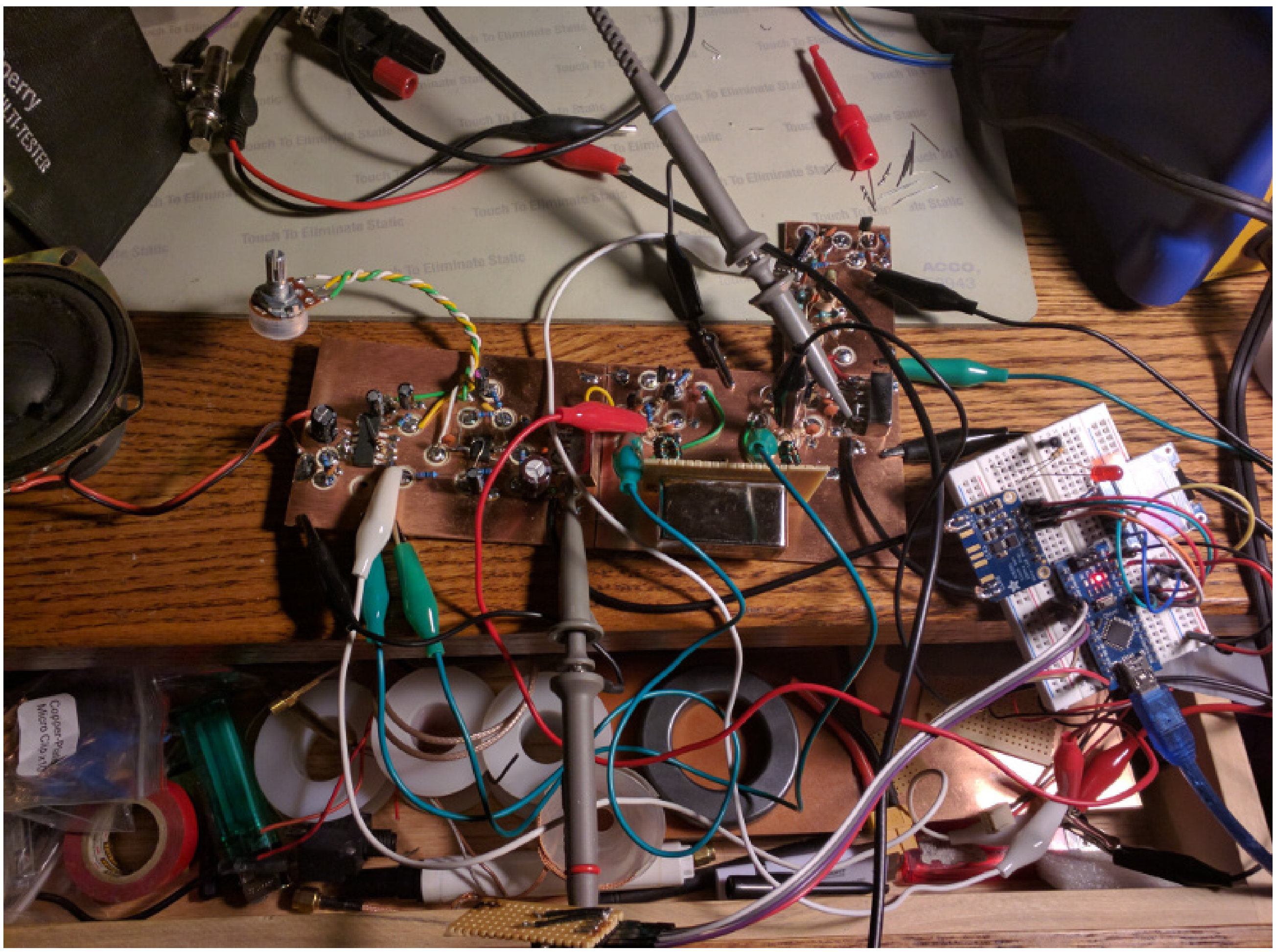
AWSH.ORG

stuff that i do and things that i make

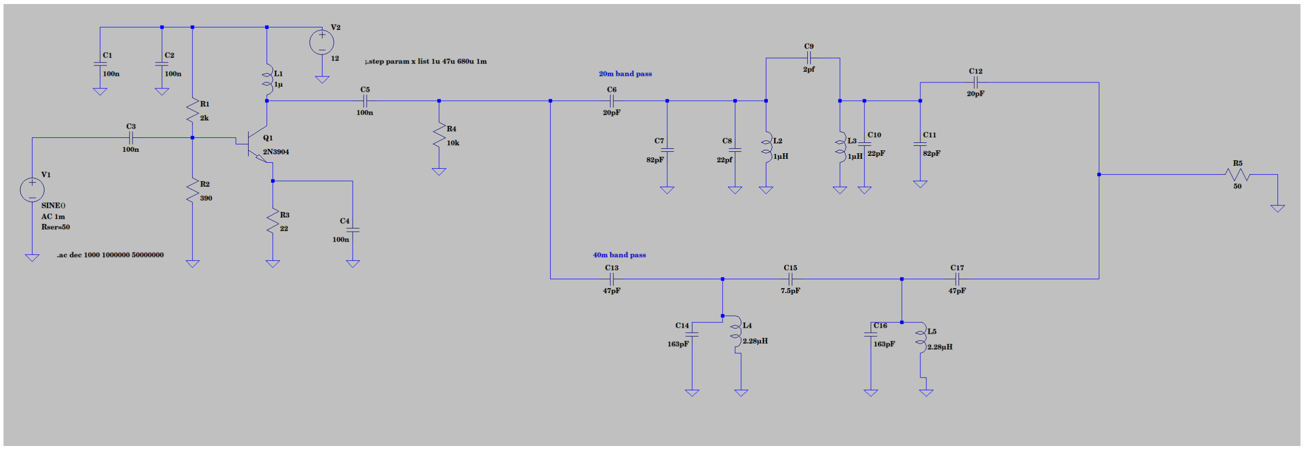
superhet receiver

PUBLISHED SEPTEMBER 18, 2017

I took the direct conversion receiver from two posts ago and converted it to a superhet receiver for 20 meters.



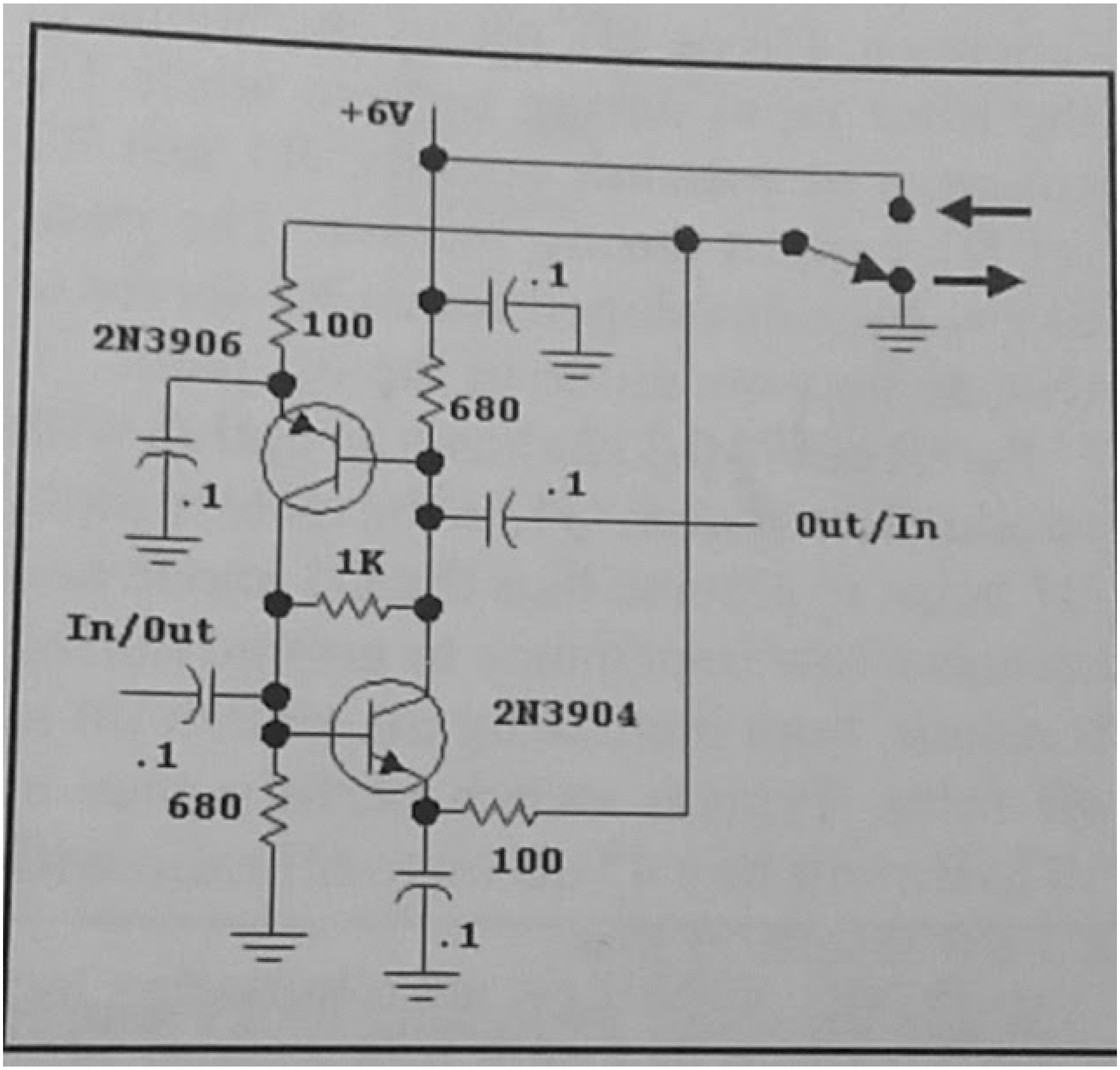
The front end starts with a simple 2n3904 rf amp that feeds into a 20 meter band pass filter.



(Ignore the 40 meter band pass. I may add band switching later.)

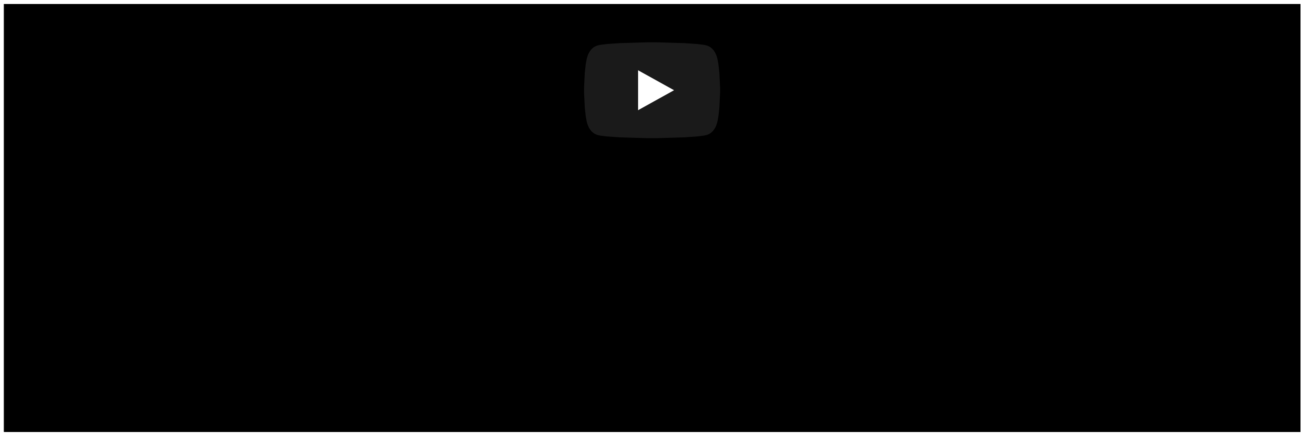
The band pass feeds into an sbl-1 mixer. An arduino/si5351 provides the vfo/bfo.

There are two identical if amps (schematic below, found on n6qw.blogspot.com) with a yaesu xf-8.9hsm crystal filter between them. I couldn't find the impedance for that exact filter, but other similar yaesu filters are at 500 ohms. I used two bifilar wound FT37-43 with 6:19 turns for the impedance matching for the input and output of the filter.



The second if amp feeds into another sbl-1 mixer and then into the same audio amp from before.

Here is a video of it working. I've still got things connected with alligator leads and splayed across the desk, but it is receiving fairly well at the moment. Next, I will attempt to make it transmit as well.



PUBLISHED IN **CIRCUITS**, **ELECTRONICS** AND **RADIO**

PREVIOUS POST
new stuff

NEXT POST
icom ic-245 & sencore mighty mite v tc142 tube tester

One Comment

mic amp – awsh.org

[…] still tinkering around with my superhet receiver. The plan is to eventually turn it into a full transceiver, but I keep getting sidetracked. I did […]

NOVEMBER 6, 2017 | REPLY

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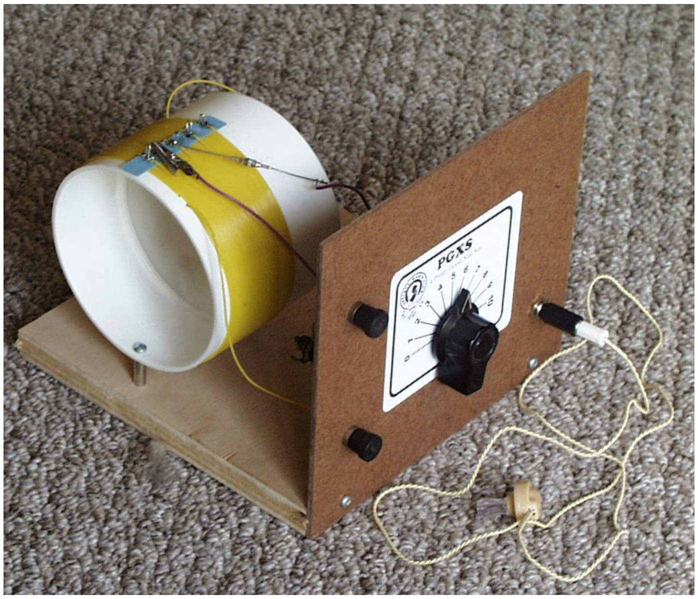
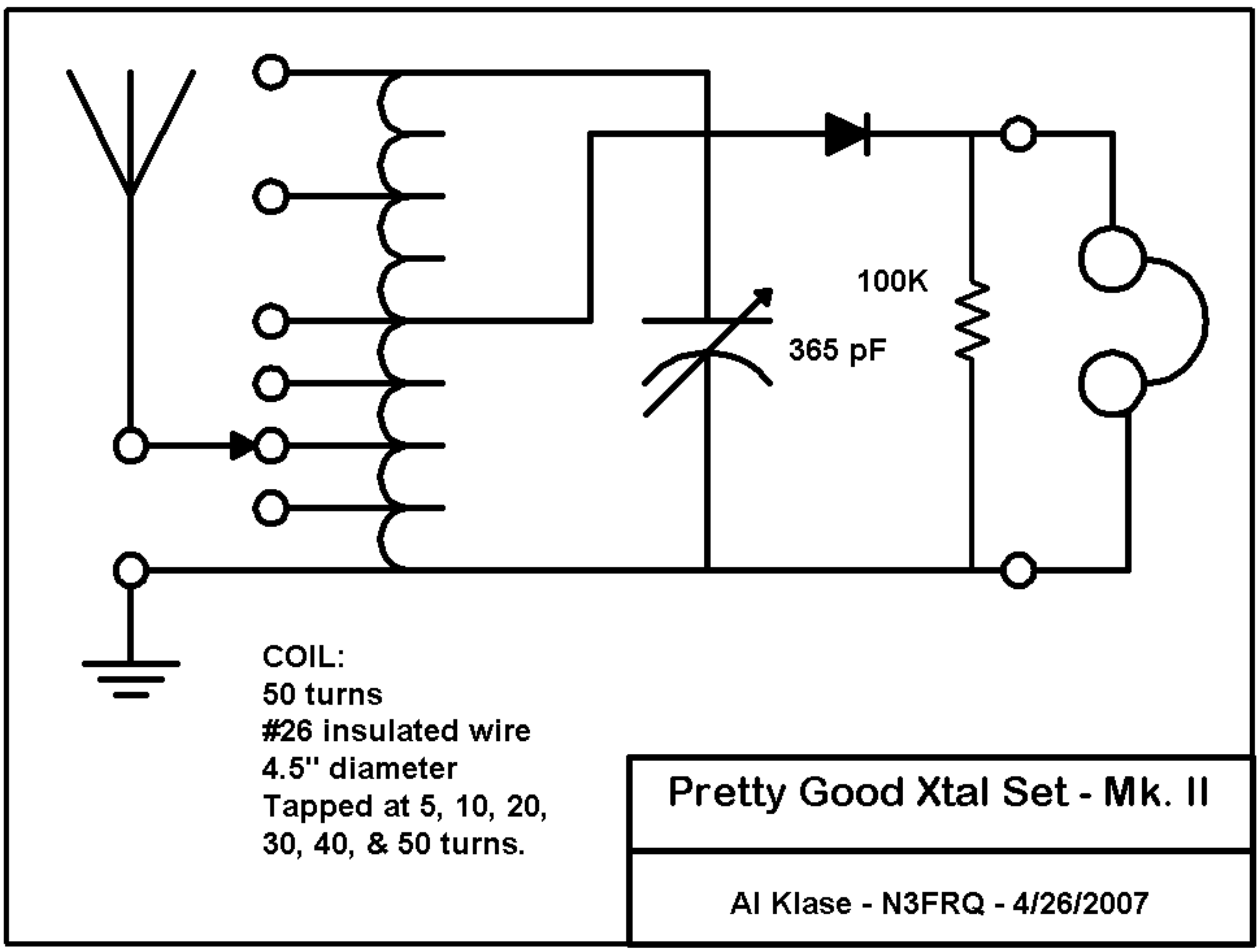
Comment

PGXS-II

The Pretty Good Xtal Set Mark II

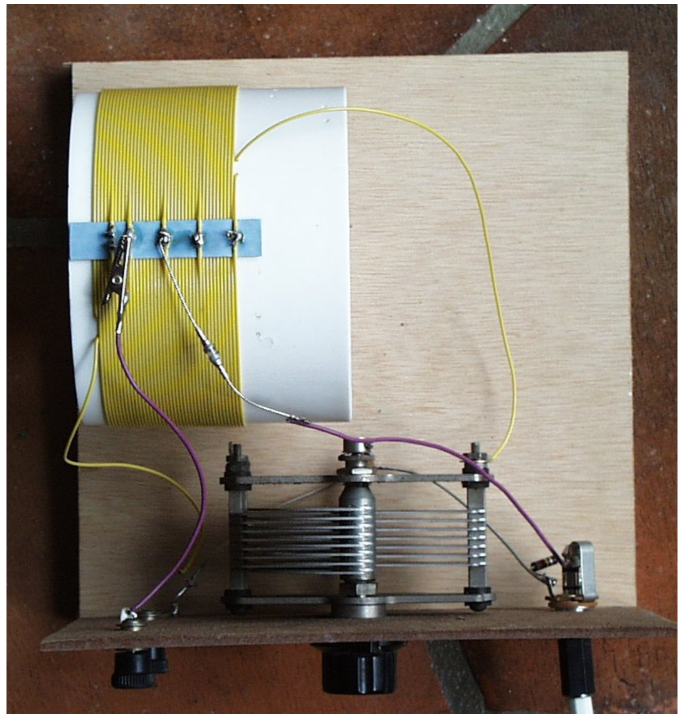


This is a revised version of the PGXS based on experienced gained with a minature set called The City Mouse.

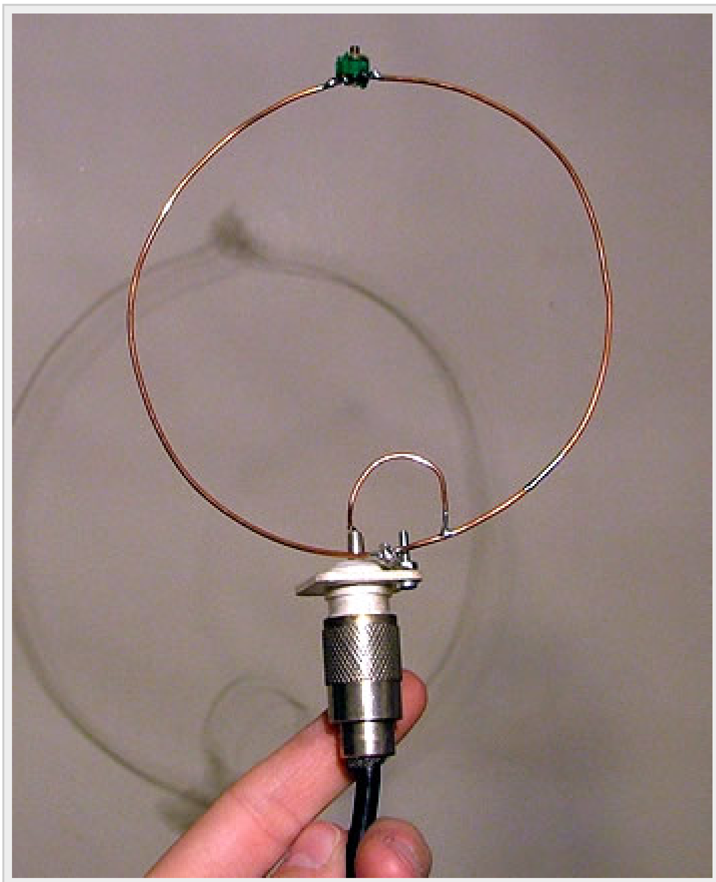


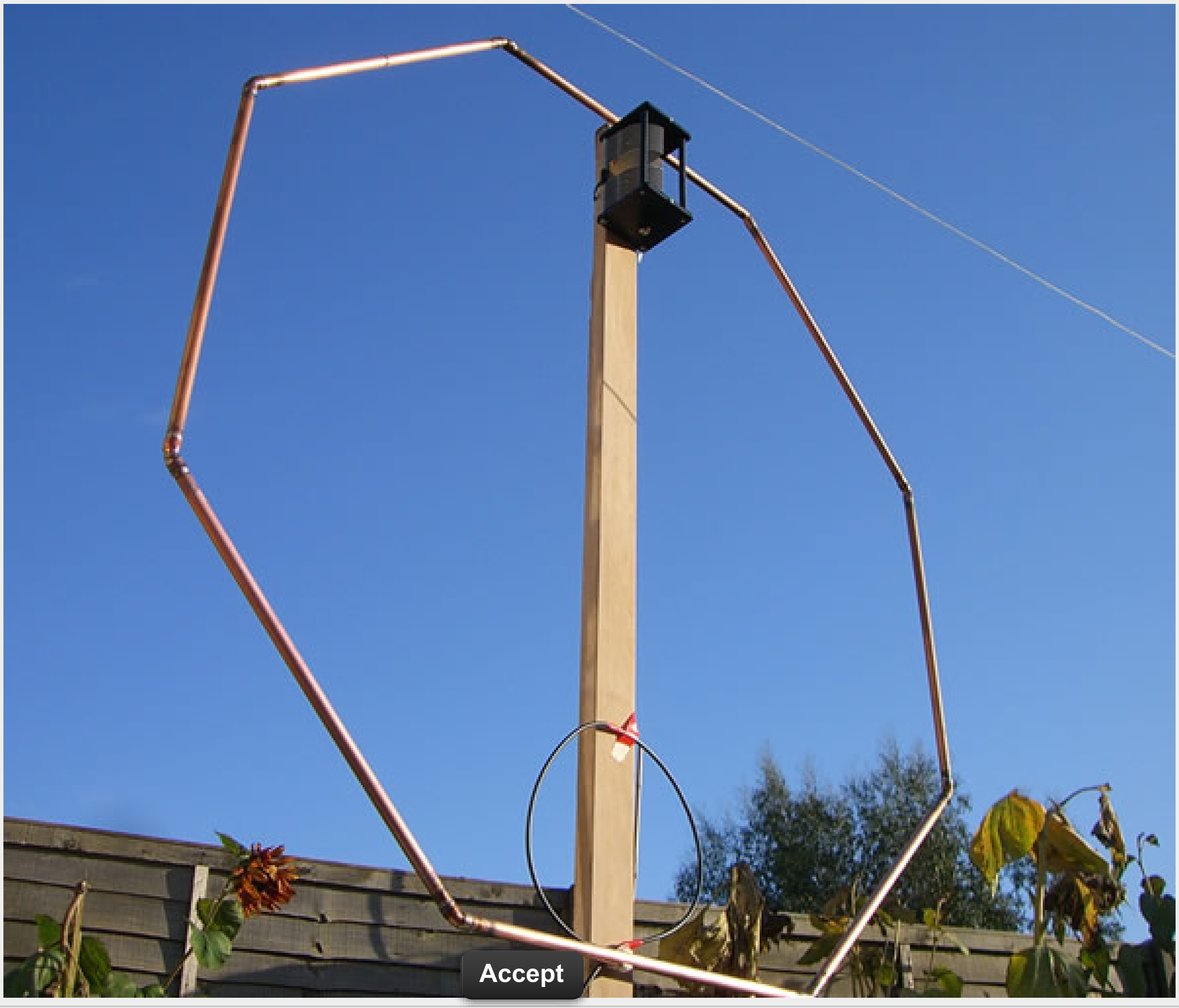
The MK. II has additional taps at the top end of the coil to better accpmodate short antennas in strong-signal areas. Follow the PGXS

link above for construction details.



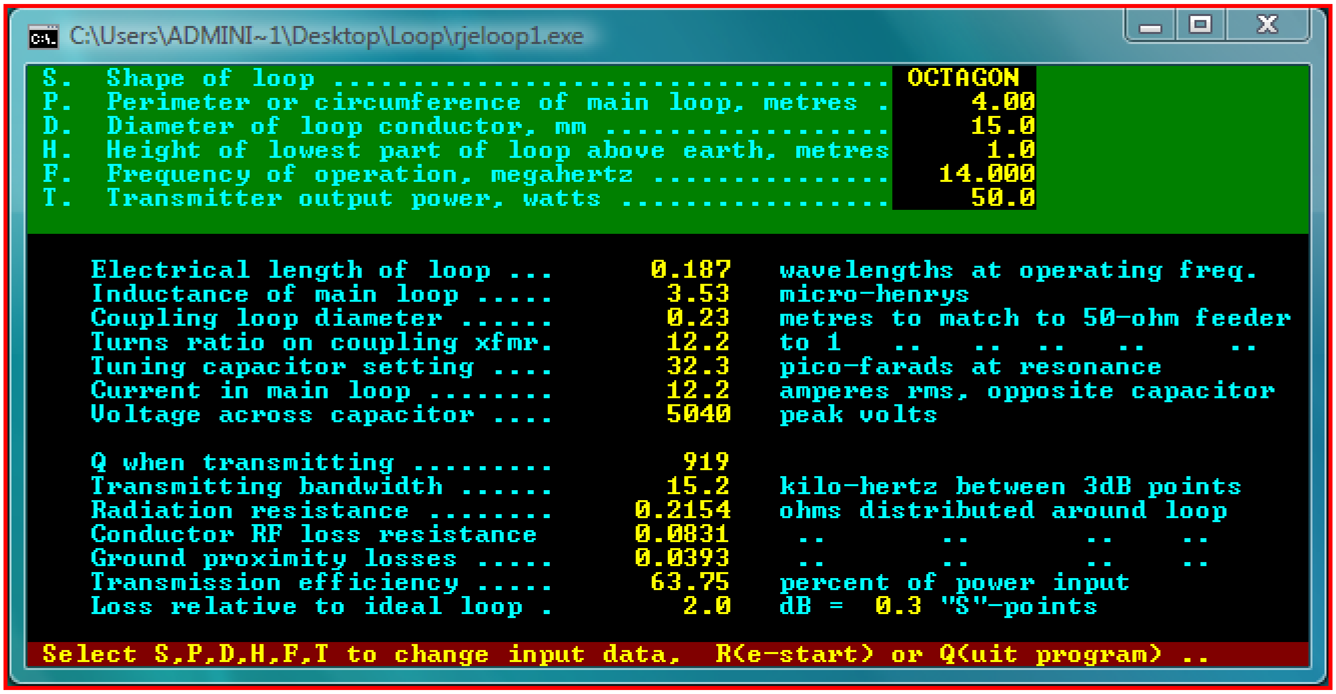
Magnetic Loop Antennas





Accept

Magnetic loop design software


C:\Users\ADMINI~1\Desktop\Loop\rjeloop1.exe
S. Shape of loop .... OCTAGON
P. Perimeter or circumference of main loop, metres . 4.00
D. Diameter of loop conductor, mm 15.0
H. Height of lowest part of loop above earth, metres 1.0
F. Frequency of operation, megahertz 14.000
T. Transmitter output power, watts 50.0
Electrical length of loop ... 0.187 wavelengths at operating freq.
Inductance of main loop ..... 3.53 micro-henrys
Coupling loop diameter ...... 0.23 metres to match to 50-ohm feeder
Turns ratio on coupling xfmr. 12.2 to 1 .. ..
Tuning capacitor setting .... 32.3 pico-farads at resonance
Current in main loop .... 12.2 amperes rms, opposite capacitor
Voltage across capacitor .... 5040 peak volts
Q when transmitting 919
Transmitting bandwidth ...... 15.2 kilo-hertz between 3dB points
Radiation resistance .... 0.2154 ohms distributed around loop
Conductor RF loss resistance 0.0831 .. ..
Ground proximity losses ..... 0.0393 .. ..
Transmission efficiency ..... 63.75 percent of power input
Loss relative to ideal loop . 2.0 dB = 0.3 "S"-points
Select S,P,D,H,F,T to change input data, R(e-start) or Q(uit program) ..

Paul Harden, NA5N • na5n@zianet.com

Part 1

The Handyman's Guide to –
HOMEBREW CONSTRUCTION PRACTICES
From Copper to Manhattan

Prepared for and published in AmQRP's Homebrewer #6 (Oct. 2005)

What is the difference between a QRPer and a Homebrewer? Not much, from what I have seen over the years. Where you'll find a QRPer, you'll generally find someone who loves to build his own equipment.

When it comes to homebrewing, there are two QRPer's that have set the standard (in my opinion). First is Bill Jones KD7S. Bill's homebrew gear, mostly crafted from ABS plastic, sets the standard that rivals professional equipment. Second is Jim Kortge K8IQY and his now famous 2N2/40 built *Manhattan style*. While this method of construction has been around for years, and many will argue who actually "invented" it, there is no doubt that Jim's 2N2/40 elevated it to a whole new level. The craftsmanship of these two master builders sets the standard many homebrewer's now strive to achieve.

Due to the continuing interest in these "build it from scratch" construction techniques, George Heron and Joe Everhart asked if I could prepare a basic guide for the **Homebrewer** based on some of the gear I have built or seen – which I am pleased to attempt. However, I make no pretenses that this is the complete guide to homebrewing. More precisely, it might be called *"Homebrewing Using Copper"* – and for good reason. Copper clad is readily available at hamfests and from many vendors (I get mine from Electronic Goldmine). Copper clad is very easy to work with, not only for the "circuit board," but for the construction of the enclosure and front and rear panels. It is also the main staple of "Manhattan Style" construction. And, best of all – it's fairly cheap!

I have used copper clad and Manhattan Style for many years myself, both for my QRP homebrewing, and prototyping circuits at work. Examples of both will be presented here.

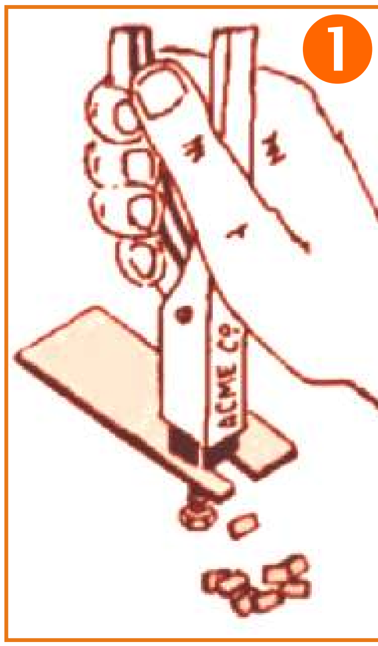
1. Let's Get Started . . .

MANHATTAN STYLE . . . What is it?

Simply put, ***Manhattan Style*** of construction uses small pieces of copper clad (the "pads") glued to the main copper clad circuit board (the "substrate") that serve as component mounting platforms. The electronic components are then mounted and soldered onto these pads. The main "substrate" board serves as the ground plane. Not only is this technique an easy and neat way to build a circuit, it also produces a very quiet circuit due to the solid ground plane.

When Jim Kortge, K8IQY, submitted his 2N2/40 at the FDIM building contest, one of the judges, Chuck Adams, K7QO, commented how the construction technique, with the IC's and electrolytic capacitors in neat rows, looked like an aerial view of Manhattan. Thus, Chuck is credited with dubbing it *Manhattan style* – the term it is well known as today amongst QRPers.

Making the "pads." There are numerous methods to make the pads. The most popular and easiest is using a ***nibbling tool*** to *nibble* out small pieces of copper clad from a larger piece, as shown in Figure #1. A nibbling tool costs $20 or less and used for making square cut-outs in 1/8" (max.) aluminum, such as for mounting a meter. The tool easy nibbles through .031" or .062" copper clad. The chards from the nibbling tool forms the pads, about 1/16" x 3/16". (Known as "chads" in Florida!).



Using a nibbling tool

Others make round or circular pads with a ***hand-punch*** tool from Harbor Freight or other sources. Dies of various sizes can be purchased for the hand-punch tool, with 3/16" or 1/4" diameter being popular sizes The tool punches-out holes in a piece of copper clad. The punched out material serves as the small, circular pads for Manhattan construction.

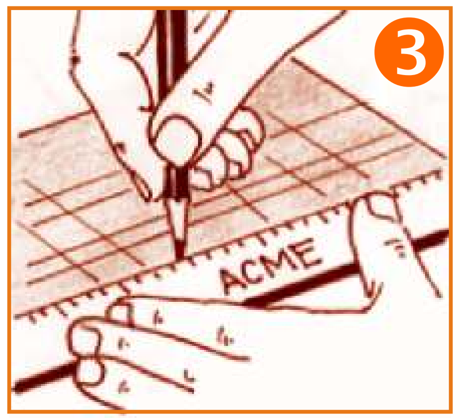
Still another method is to snap-off pads from a piece of ***perforated copper clad board*** as shown in **Figure #2**. The pads are twisted off with a pair of needle nose pliers or cut apart by a hefty pair of wire cutters. These pads are not as "pretty" as those made by a nibbling tool or circular hand punch, but work equally as well. The board can also be cut by following the perforated holes, using a coping or hack saw, to produce long strips, which can be cut-off at the desired length. One advantage of this technique is it allows you to make long strips that can serve as the +Vcc bus or making longer runs without having to connect two smaller pads with a jumper wire.

Using perforated copper clad circuit board for making the pads is another method, requiring no special tools.

Pads can be made from .031" or .062" thick copper clad, single sided or double sided.

Once the pads are made, it's a matter of placing them on the main circuit board for mounting the components. Before gluing on the pads, it is best to plan ahead.

Laying out the circuit. It is recommended to lay-out your circuit on a piece of paper, arranging the components in a logical circuit manner, similar to laying out a printed circuit board with paper and pencil. This will ensure that all of the components will fit on the size of copper clad board you have selected as the circuit board or substrate. One can build Manhattan Style by "building as you go," but problems fitting components, working yourself into a corner, or ending up with long wire runs reaching front panel controls can occur. Planning ahead by laying out the circuit first is by far the best way to ensure the finished product is correct to the circuit, functional, and the final appearance is nice and neat.



Draw footprints of each section and guidelines with pencil on the copper clad board. Planning ahead is important!

Once this is done, transfer the layout to the copper clad board with a ruler and pencil as shown in **Figure #3**. This provides guidelines for gluing down the pads and keeping things straight, square and symmetrical.

Gluing down the pads. Once the circuit has been layed-out, it is time to mount the pads on the main substrate board with small drops of super glue, as shown in **Figure #4**. And, small drops is the secret! Learn to issue a very small drop, smaller than the size of the pad, to keep excess from being squeezed out over the board when you apply the pad. It takes a little practice, but you can learn to apply the right amount with little waste.

Pads are "mounted" to the main circuit board with glue – usually with super glue. The secret is learning to administer a small drop of glue. This comes with practice.

There are many opinions as to what type of super glue works the best. Some prefer one brand over another, some prefer the gels. I have tried them all and have found little difference between them other than personal preference. I build most of my Manhattan circuits with the cheapest glue I can find, which is usually Duro-Bond Super Glue, with two tubes per package costing $1.79 or less at Wal-Mart or local hardware stores. The small "snout" on the tube is also relatively easy to keep clean and open.

The biggest problem I have found with different manufacturers or with the exotic applicators is keeping them clean. They work great – the first time.

But, when you come back to work on the project the following night, that fancy $5 tube has super-glued itself shut. You either can't get the protective cap off, or the tube has turned into a solid brick. Time for a new tube. A couple of cheap tubes of super glue goes a long ways when this happens.

To avoid these problems, I usually do two things when I'm done for the day:

1) Remove the applicator tip and run a resistor lead down the spout to open up the channel from excess glue. The excess may run or drip out the end. This will ensure the applicator tip is "open" when you place the tip back onto the tube. Without doing this, the super glue left in the tip can turn solid and hard, preventing it from being used again.

2) Clean the applicator tip and protective cap with a Q-tip or paper towel soaked in alcohol or acetone. Clean off all access glue, particularly on the threads for the protective cap. Then, clean dry with a piece of paper towel. If the paper doesn't stick – it's clean! This will ensure you'll get the protective cap off the next time you use the tube of glue.

These two simple cleaning steps can keep a tube of super glue useful for a long time. If not, that's why the cheap tubes of super glue should be used.

Positioning the "pads." The pad is placed on the drop of super glue and positioned into exact placement with an Exacto knife or other sharp object, as shown in **Figure #5 and #6**. For the first few seconds, the super glue will be slippery, allowing the pad to be easily positioned. Once in the desired position, push down on the pad against the main board to squish against the glue. It will be solidly glued into place in a few seconds.

The method I often use is to place the pad into position with a pair of sharp, needle nosed tweezers. Once in position, I push down on the pad with a small screw driver or the wooden shaft of a Q-tip. However, the tweezer method does not work well when using the punched-out circular pads.

After several seconds, the pad should be firmly attached to the substrate board. Some of the circuits I have built years ago using this method have the pads still firmly affixed to the board.

To remove a pad that got positioned in the wrong place, simply "twist it off" the board with a pair of needle-nosed pliers, as shown in **Figure #7**. Any pad that becomes dislodged from the board can be simply re–glued into place with a new drop of glue and holding in place for a few seconds.

Cleaning up. Once the excess glue had dried, it can be scraped off the board with a hobby knife or a small flat blade screw driver. It's up to the builder how picky one wishes to be with this. At a minimum, the board and pads should be cleaned with a hobby brush or toothbrush moistened with alcohol or acetate to remove oils, fingerprints and debris. This will make for easier soldering and a nicer appearance.

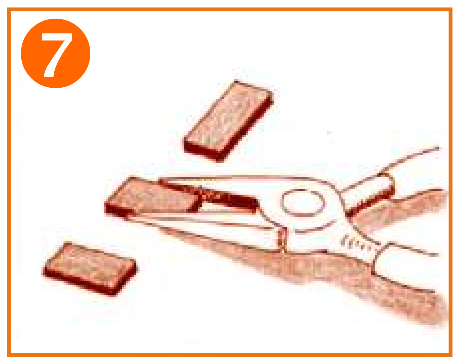
Acetone dissolves dried super glue better than alcohol. It is easily obtainable as fingernail polish remover in many stores. However, most fingernail polish remover sold today is "acetone free." Ensure you get a bottle that contains real acetone. I get a bottle of acetone based fingernail polish remover from Wal-Mart that works quite well. It costs 88 cents for a pint bottle and usually lasts for several projects.

5

6

Place the pads onto the drop of glue and position with an Exacto knife, other sharp object or tweezers..

7

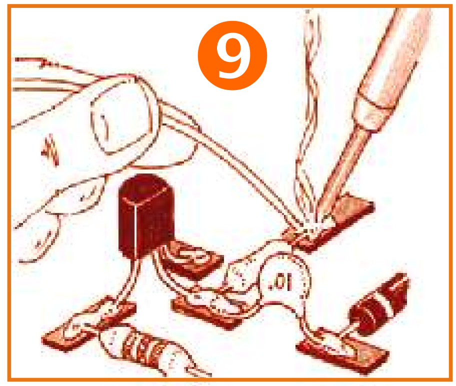


Remove a pad by a twist with a pair of needle-nosed pliers.

8

Clean board and pads with a brush and alcohol or acetone.

Melt solder! Once the pads are in place and cleaned, there is nothing left to do except mount the components onto the pads and solder in place according to the layout drawing. Of course, ground connections are soldered directly to the main substrate board, being the circuit ground plane, as shown in **Figure #9**.



The glued pads become the mounting platforms for the components, soldered in place.

I use a small hobby brush with hair or fiber bristles (not steel) for cleaning the pads. I use the same brush moistened with alcohol or acetone for cleaning the pads after soldering. This removes excess flux and debris, leaving a nice, shiny soldered pad.

Tools. In addition to the obvious — a soldering iron, wire cutters and the small pliers already discussed, several other small tools come in handy:
Tweezers are handy for positioning the pads when gluing to the board, in addition to holding small parts while soldering – particular surface mount components. *(Surface mount techniques will be presented in Part 2).*
Hemostats are another useful small tool for holding resistors or capacitors while soldering. They are locking, making it easy to hold the component with one hand while soldering with the other. Just ensure you don't over-squeeze the component to cause damage. Hemostats often allow a component to be held with a better grip than with tweezers.
Small screwdriver, flat-blade or phillips, is useful for holding down pads while the glue dries, pushing down ill-bent or stubborn component leads while soldering – even a lead bender to ensure smooth bends on component leads and internal wiring.
Q-tips are handy for cleaning or scrubbing around the pads after soldering, where a hobby brush may not often reach. Lightly moistened with alcohol or acetone, they are also useful for cleaning the components. When cut in two, the wooden shafts are also handy for holding down pads during gluing, or components while soldering.

Some of the small tools useful when building Manhattan style.

2. Some Practical Examples

THE ROCKMITE QRP TRANSCEIVER

Like hundreds of others QRPers, I built a ***Rockmite*** about two years ago when the kit was first introduced. The Rockmite QRP transceiver is a kit from Small Wonders Lab, furnished with a printed circuit board. I decided to highly modify mine, building it in a custom enclosure with a set of homebrew built–in paddles, something I always wanted to do. Additionally, it served as a test platform for a 5W Class-E PA circuit. The entire rig, including the paddles, was built of copper clad, except for the top cover, made from a scrap piece of perforated aluminum and painted black.

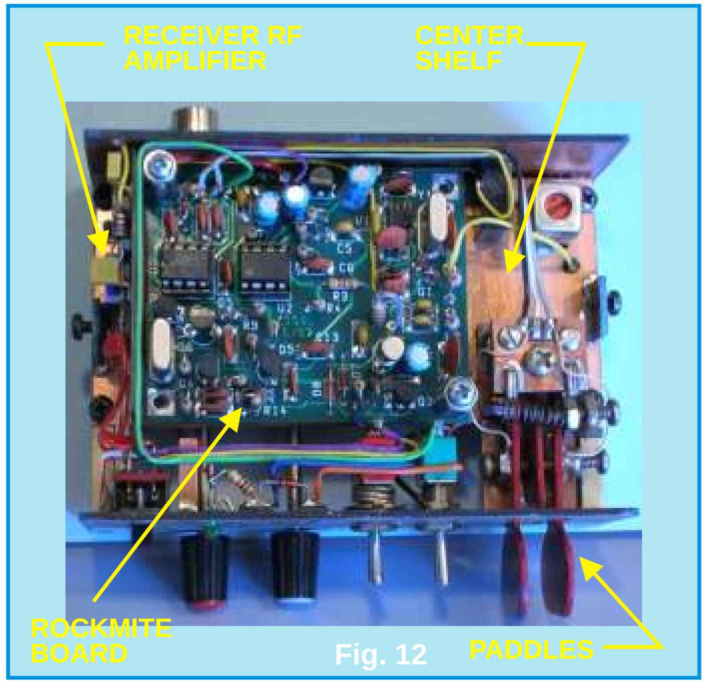
Fig. 11

The front panel, shown in **Figure 11**, was made from a piece of copper clad. Holes were drilled and the "square holes" for the power switch and paddles were filed to shape with a small jewelers file. After drilling, the copper clad was brushed with emory paper to rough up the copper a bit before applying a light coat of gray primer paint. The second coat, applied the following evening (this is a big hint for painting enclosures!) was a coat of light avocado green. The following evening, when fully dry, the light blue trim and boxes for the transmitter drive and receiver RF gain controls were painted by hand using a small brush. The legends were applied using rub-off

letters and sealed with a light coat of Krylon Protective Spray – available at many office supply or art stores. Clear enamel can also be used, but always test first on a scrap piece of material to ensure it doesn't "melt" the rub-off letters.

The front and rear panels were soldered to a copper clad "center" shelf, mounted about half the height of the two panels. This shelf serves to mount the Rockmite PCB and the paddles on the top (see **Figure 12**), and the transmitter components on the bottom.

The paddles are made entirely of pieces of copper clad, including the paddle pieces, as shown in the photograph of the top view. A 4-40 bolt and nut, with a spring from a BIC pen, formed the tension on the two paddles, while two other 4-40 machine screws serve as the dit and dah contactor and sets the spacing. It's not exactly a work of art, but they worked well, enough to have around 50 QSOs with this rig.

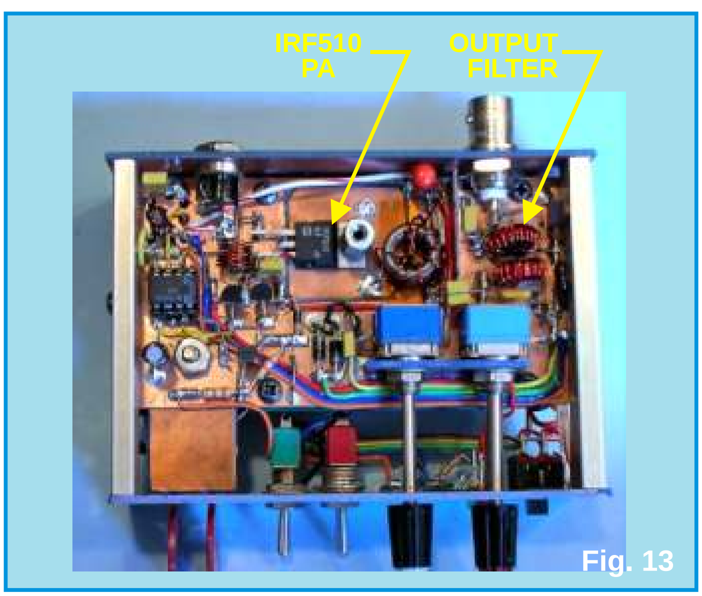


Top view of the Rockmite. The Rockmite PCB and the homebrew paddles are mounted on the top portion of the center shelf.

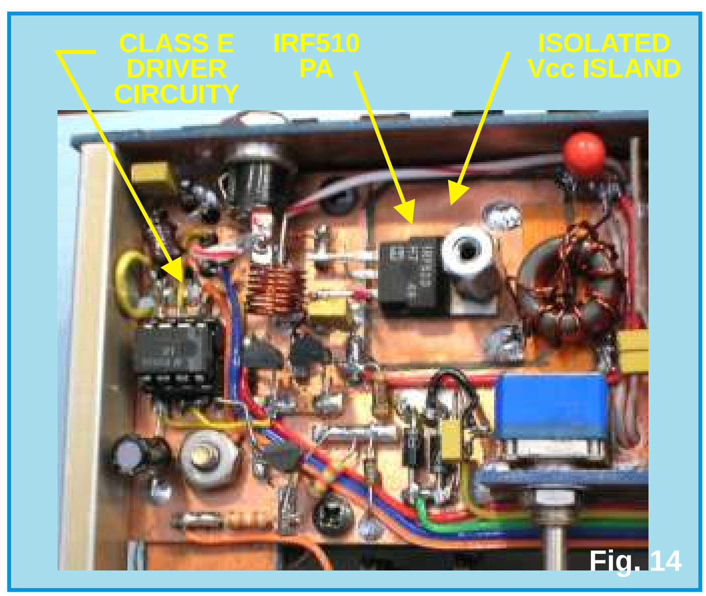
The transmitter was built Manhattan style, with the pads glued directly to the bottom of the copper clad shelf. The IRF510 was mounted to an island cut-out of the copper clad by a Dremel tool. Since the IRF510 tab is the drain, this isolated the +12v on the drain tab from ground. Most of the interconnecting wiring was performed by using flat ribbon cable as shown in **Figures 13 and 14**.

The intent of this particular custom-made Rockmite kit is to show the flexibility of copper clad. It was easy to form the copper pieces into the desired front and rear panels, the center shelf, and even the paddle pieces. Granted, it took a little cutting and filing to form some of the pieces, but far easier than forming the same pieces from aluminum or metal stock. Plus, it can all be easily soldered together.

By applying a light primer coat before the final color of spray paint, copper clad makes an attractive and durable front panel as well.



Bottom view of the Rockmite, showing the home-brew transmitter section built Manhattan Style.



A closer view of the transmitter section, showing the Manhattan style of construction.

MANHATTAN STYLE HOMEBREW TRANSCEIVER

I have built several QRP transceivers on different bands Manhattan style, mostly my own designs. In fact, that is one of the advantages I have found with Manhattan is how adaptable it is for a test platform. Changing components of different values to set proper biasing or gain is relatively easy, as is making circuit changes. Of course, too many circuit changes can get ugly as you try to fit things in you didn't originally plan on. But, it usually works fine. In the circuit shown here, I converted the RF amplifier from fixed gain to an AGC driven stage, moving around a few components from that originally planned.

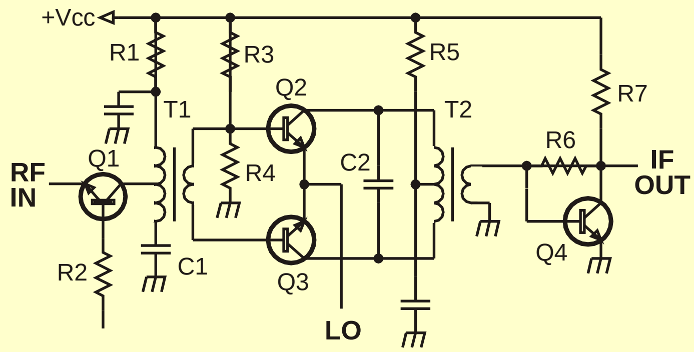


Fig. 15
Functional Schematic of the 40M "front–end"

The schematic (**Fig. 15**) is the "front end" portion of a 40M receiver I built, where T1 and T2 are Mouser 42IF124 IF cans. Q1 is a common base amplifier with the bias via R2 from the AGC line. C1 and C2 are the tuning capacitors to resonate T1 and T2 at the desired frequency (T1,T2 are 4.5uH nom. with no internal tuning capacitor). T1 is made resonant at the RF frequency and T2 at the IF frequency. Built Manhattan style, this RF amplifier and mixer scheme was fairly sensitive with a good noise figure.

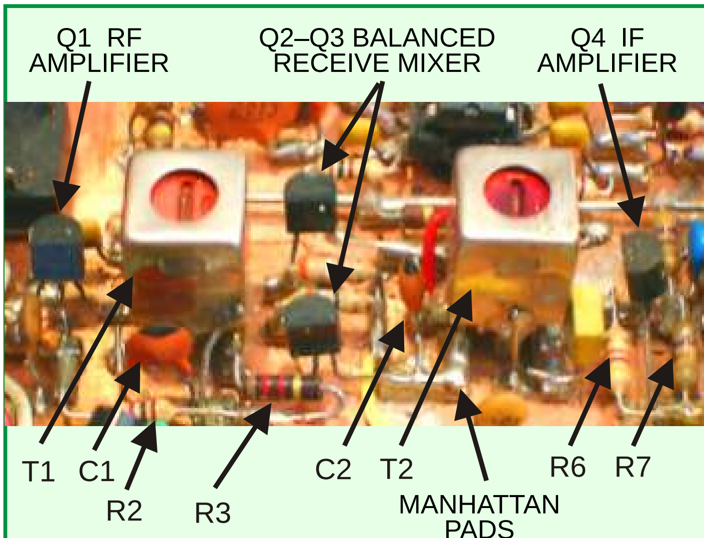
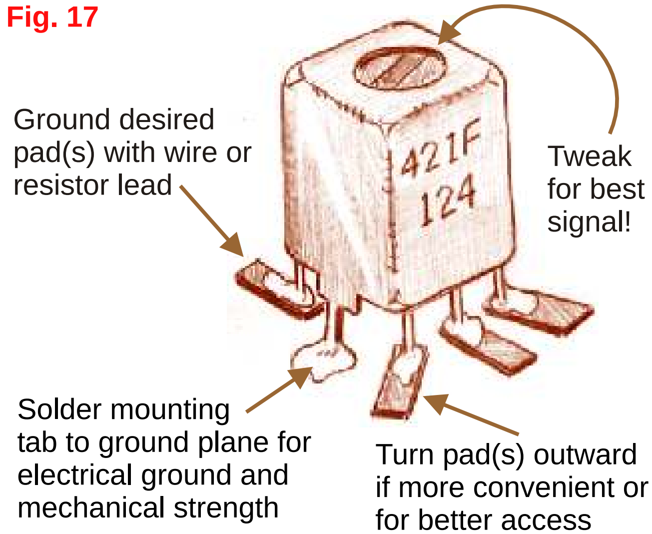


Fig. 16 – The "front-end" of a 40M QRP receiver built Manhattan style using IF "cans."

The **Figure 16** photograph shows the "front end" portion of the receiver, based on the above schematic. With a little layout on paper first, the RF amplifier, receive mixer and 1st IF amplifier fits in an area about 1 x 2.5 inches. Interestingly, I also built a surface mount version of this same receiver, using the same IF transformers, and it took only about 1/4" less space! I used SOT-23 SMC 2N3904 transistors, which are about the same width as the TO-39 plastic versions. As a result, little space savings was noted – at least using this layout configuration.

The IF transformers are mounted on the main board in standard Manhattan style. See **Figure 17**. The only caution is to ensure the IF "can" is soldered to the main board with either the mounting tabs (if they reach) or with a piece of solid bus wire or a scrap resistor lead folded in two. Solder on two adjacent sides of the IF can for a firm mechanical connection.

Fig. 17



Mounting IF Transformers Manhattan style

Likewise, ground the desired pads(s) by soldering a wire or resistor lead to the main board for grounding. All transformer pins should go to a Manhattan pad to keep the IF transformer "level." Soldering the wire to ground the pad(s) to the main board also helps with the mechanical mounting without depending solely on the super glue. Otherwise, with a "stiff" IF can, you can twist the pads off the board while adjusting the center slug if not soldered directly to the board.

Following the 1st IF amplifier is the crystal ladder filter, as shown in **Figure 18**. Four of the crystals are for the IF filter, the one on the far left is actually the crystal for the transmit oscillator. The transistor in the upper left of the photograph is Q4, the 1st IF amplifier in **Figure 16** on the previous page. The wire soldered along the tops of the crystals serve two purposes: 1) to ground the cans to the main board, and 2) provide mechanical rigidity. Without this ground wire, I find myself constantly bending over the crystals while I'm building and poking around in the circuit.


Figure 18

The IF Crystal Filter

Figure 19 shows in a bit closer detail how the crystals and shunt capacitors are mounted to the Manhattan pads.

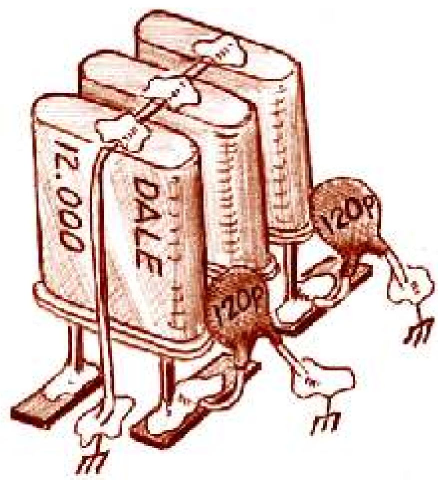


Figure 19

In mounting the crystals on standard Manhattan pads, the crytal leads need to be bent to fit. This is a case where cutting small strips of copper clad to length makes for a neater and more accessible assembly.

Figure 20 shows the LM386 audio output amplifier I.C.. This is such a simple, yet effective audio amplifier, it has become the benchmark amplifier in most QRP rigs.

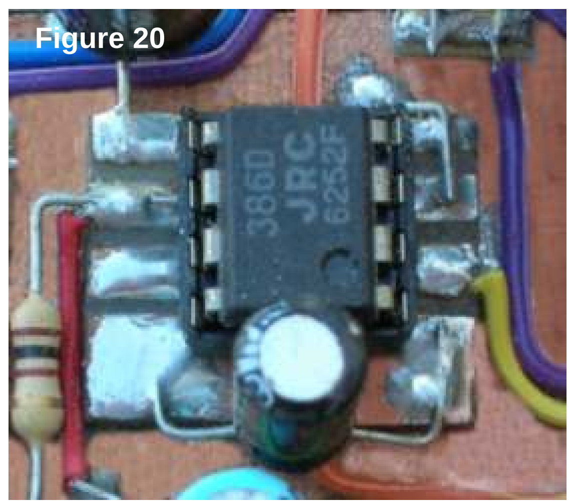


Figure 20

The LM386 Audio Output Amplifier IC

I mount ICs either on individual Manhattan pads, or build a single pad as shown in the photo of **Figure 20**. This pad is made from a single piece of copper clad, cut into the pads as shown by sawing away the copper between the pins with a hack saw, coping saw, or a Dremel tool with a cutting disk. Then, obviously, another cut down the length of the IC to separate pins 1–4 from 5–8. Either method takes about the same amount of time, though the single Manhattan IC pad does look nicer, in my opinion.

If you make a rig out of copper clad, including the front and rear panels, don't forget the copper on these surfaces can be used as well. **Figure 21** shows one rig I built with the PA output filter mounted on the inside of the rear panel, next to the Antenna BNC connector. In this particular case, I etched away the unwanted copper with a Dremel tool, though Manhattan pads could just as easily be used. To the left of the filter (not shown) is the TO-220 PA transistor – also mounted on the inside rear panel. This allows the rear panel to serve as a large heat sink.

Figure 21

The PA Output Filter mountedon the inside of the rear panel saves space

A MANHATTAN BUILDING JIG

A building jig for holding down the circuit board for Manhattan style of construction.

One of the difficulties I've experienced building small circuits is the copper clad board, weighing only a couple of ounces, moves all over the workbench surface as you work on it.

Shown in the photograph is a Manhattan Building Jig (MBJ) I built for holding down a circuit board while it is being built and tested. In this case, I used a piece of aluminum and milled out several slots. In these slots ride the screw heads for the threaded standoffs. On the top of the standoffs, the washers and nuts secure the circuit board. Once attached, the screws on the bottom of the plate are tightened to hold everything rigidly in place. This allows different sizes of circuit boards to be mounted onto the jig. I have found this simple jig to really ease construction and testing. Particularly testing. Once you get a couple of cables and wires connected to the board, the weight of the cables alone will pull the board right off the bench! A jig with a little weight and larger footprint will keep this from happening.

On the far right hand side of the jig, under the circuit board and hardly noticeable, is the TO-220 voltage regulator used for the circuit. This places the voltage regulator close to the circuit and the base acts as a heat sink.

Of course, a jig of this nature could be built out of plywood or even a piece of 2x4. In this case, the board is held down to the jig with wood screws or other fastening scheme.

MANHATTAN – VHF STYLE

One of the "modules" I am responsible for at the VLA observatory is called the "4/P Converter." This converts our low-band receivers, being 74, 196 and 308–348 MHz, to an IF of about 1.1–1.4 GHz (L-band), then upconverted again to our 8–12 GHz X-band IF. In order to checkout this upconverter, I would need 4 signal generators, one for the three receivers and one for the 1024 MHz LO. I'd get killed by my co-workers for sucking up 4 of the lab signal generators everytime I needed to work on this converter! And, I've got 28 more of them to build over the next 3 years. So, I designed and built a test set that simulates the three receivers and the 1024 MHz LO. Additionally, it contains a sweep generator for "sweeping" the bandpass shape of the RF and IF filters on a spectrum analyzer.

Fig. 23 – A Manhattan-built Test Set used to simulate three VHF receivers and contains a 1024 MHz Local Oscillator

This was a fun "ham radio" project at work. It was built largely from copper clad and Manhattan style. Most of the parts were ordered from Mouser, All Electronics, Electronics Goldmine and MiniCircuits. The overall "4/P Band Test Set" is shown in **Figure 23**. The copper clad circuit assemblies are mounted vertically with the push-button switches and potentiometer controls protruding through the front panel. Details of two of these assemblies, the 74MHz oscillator and the 200-400MHz sweep oscillator, are shown on the next page. The meters indicate the output power level, normally set to –35dBm to simulate the receivers. While this is not a ham radio QRP project, it does contain many construction techniques that can be applied to any HF or VHF project. (Although, it *was*

built by a QRPer!). When I built this, I was a bit concerned at how the copper clad and Manhattan pads would behave at the VHF frequencies..It turns out, it works quite well. Wideband sweeps reveal only minor gain "suck-outs" between 600-1500 MHz. Rumors that Manhattan style should not be used above about 20MHz are thus unfounded, as proven with this project.

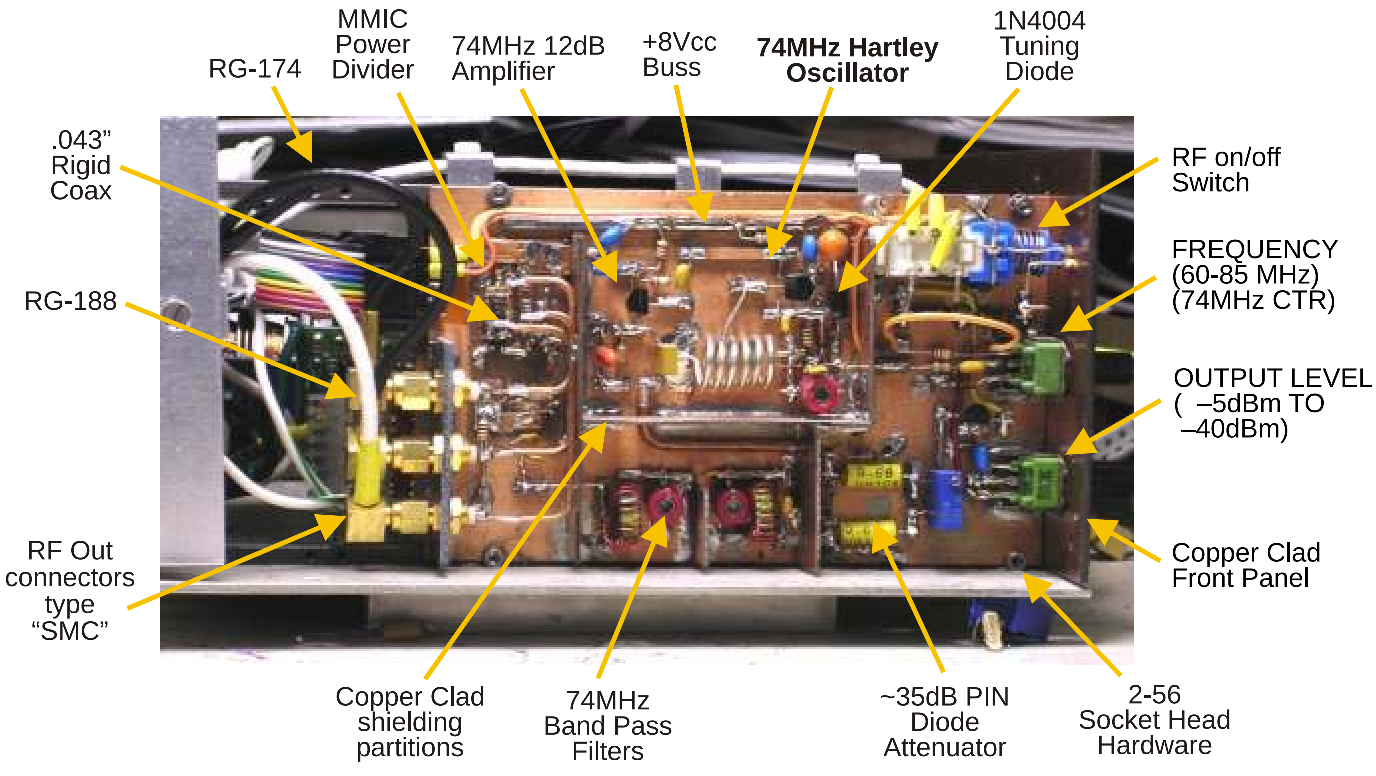


FIG. 24 — 74MHz OSCILLATOR (74MHz RECEIVER SIMULATOR)

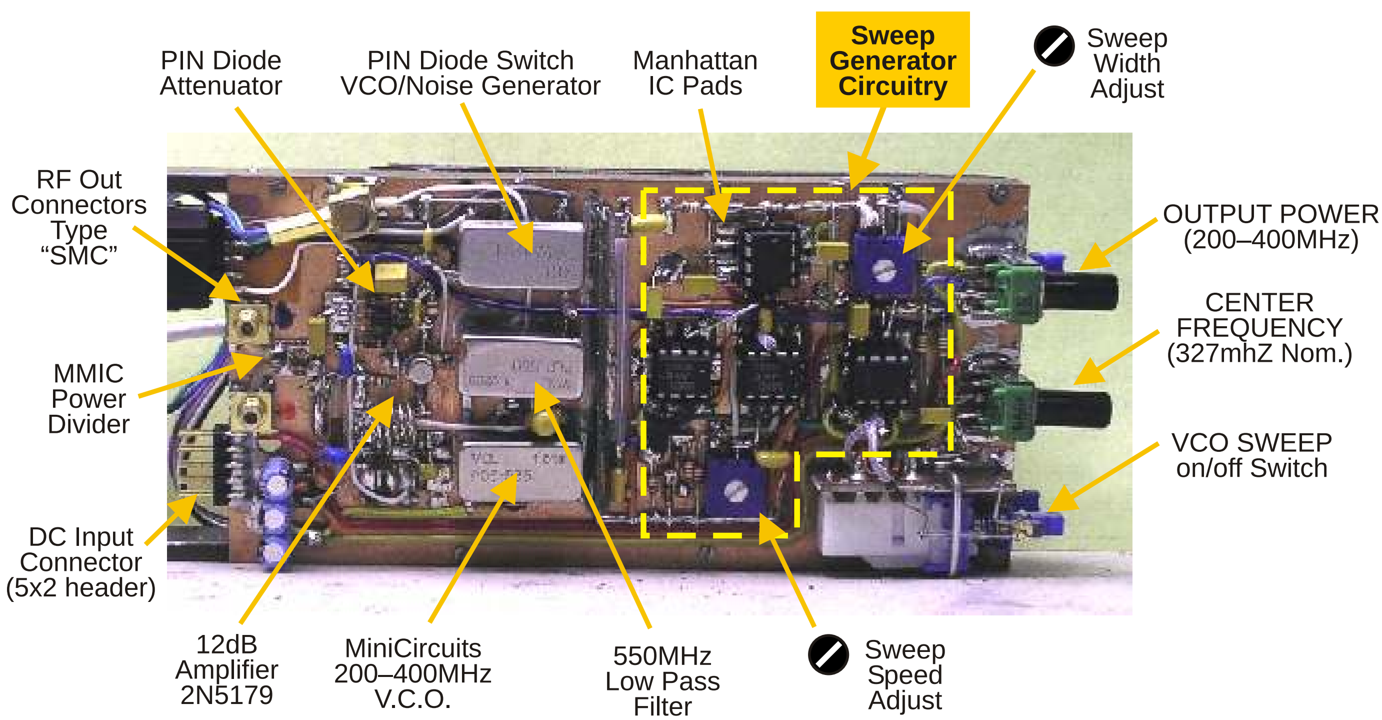


FIG. 25 — 200–400MHz SWEEP OSCILATOR (P-BAND RECEIVER SIMULATOR)

3. "Ugly" or Manhattan?

While the majority of this article focuses on Manhattan style of construction, it is not the only means to build a circuit. Since the dawn of radio, hams have built equipment "ugly style." Ugly has a charm of it's own.

Ugly began in the earliest days of vacuum tubes, where a circuit was built on a piece of smooth wood, mounting components between nails or screws – often just twisting the wires together, not soldered. Since a cheap piece of attractive wood in the early 1900s was a breadboard used by bakers, the term for this style of construction was called "breadboarding" – the genesis of the term still used today for building a one-of-a-kind circuit. Building on a breadboard could be anything from beautiful (**Fig. 26**)– to outright ugly.

Basically, building something ugly means "just throw it together" with little regard to appearance. Ugly also tends to imply building it cheaply as well, a common attribute of most hams – yesterday as well as today.

Today's breadboard tends to be a piece of copper clad. Component leads that are grounded are soldered to the copper clad surface as in Manhattan style. Everything else just gets soldered together, often with the components hanging in mid–air. The only concern is to make sure the component leads to do not touch ground or other things they shouldn't – often by bending or routing leads and wiring in a precarious manner. An example of this is the 7 MHz VFO built "ugly" as shown in the photograph of **Figure 27**.

A variation of the ugly circuit is called "dead bug." This technique is where the integrated circuits (the "bugs") are glued (or not) to a surface, face down, with the IC pins sticking up in the air for easy access. Wiring and components are soldered directly to these pins.

Regardless of the ugly method used, the circuits usually perform quite well. The biggest problem is stray capacitance from the often long component leads and wiring hanging in mid-air and in close proximity to each other. However, once the circuit is "tuned" to account for the stray capacitance, the circuit will work reliably – as long as you don't move or rearrange anything!

This becomes one of the biggest problem in ugly construction – duplicating the circuit. It often works fine for the first person building it, but when the circuit is built by someone else, results may vary. This is why early QRP publications seldom detailed how the circuit was built, as it was difficult to document to show exactly how the circuit was built.

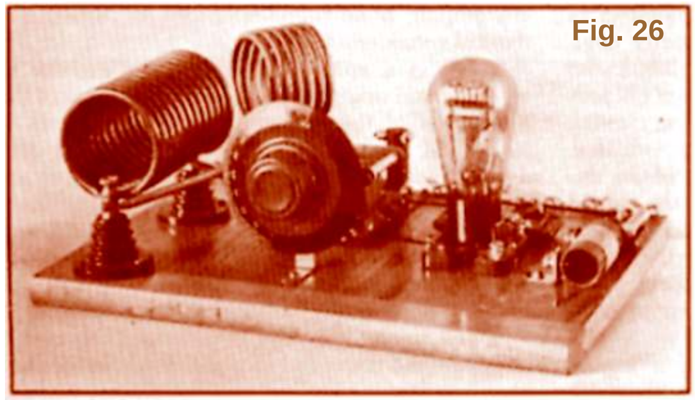


Fig. 26

From 1933 ARRL Radio Amateur's Handbook

Early ham equipment was often built on a standard 10 x 12.5 inch bread board, such as this 1930s "7000 kc low-power transmitter."

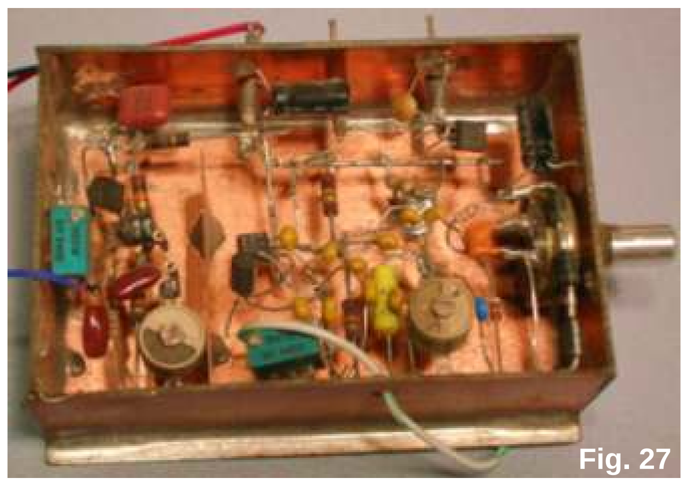


Fig. 27

The modern "breadboard" is often a piece of copper clad. This 7.0 MHz VFO was built "ugly style" in a copper clad "box."

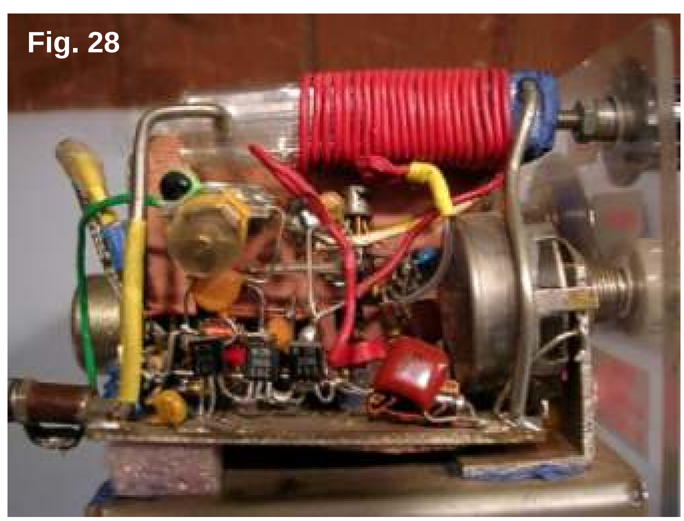


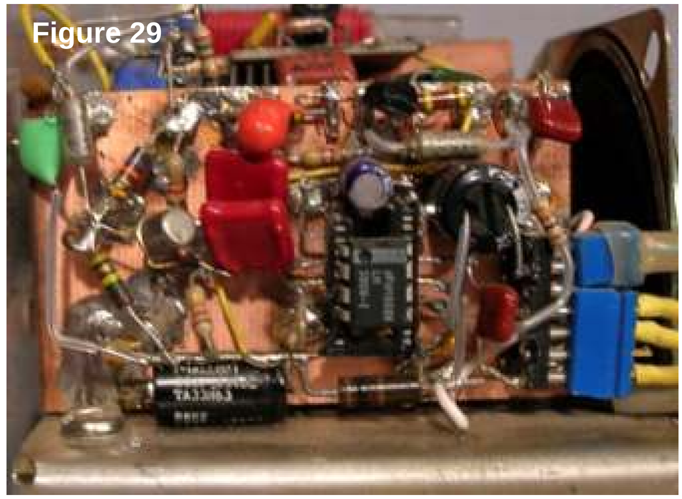
Fig. 28

A regenerative receiver built ugly style on a piece of copper clad. The coil is wound on an IC shipping tube.

In my opinion, this is the strongest advantage of Manhattan style for QRPers ... it is easy to document. Photographs or drawings illustrate exactly where each component goes and how it is built, ensuring consistency in construction amongst the various builders. This consistency also ensures the performance of the circuit will be about the same from unit-to-unit. This is why those people building Jim Kortge K8IQY's 2N2/40 were so satisfied with the results. Those who built it from the detailed drawings in the original QRPp article, the book, or on Jim's website, all ended up with a hot 40M transceiver with very similar performance to Jim's original. Had the 2N2/40s been built "ugly," this consistency in performance could not have been guaranteed. How would you document with any degree of accuracy the "ugly" circuit shown in **Figure 29**?

This is why Manhattan style has become so popular with QRP homebrewers. The designer can *clearly* illustrate *exactly* how to build the circuit to guarantee the expected results. The builder has *precise instructions* to follow and can build the circuit with the confidence it will work. This is true with the seasoned builder as well as the beginner. This is why Manhattan style has become the biggest boost to building a circuit "from scratch" by QRPers. Circuits designed and built Manhattan become excellent construction articles, since the step-by-step instructions lie mostly in the illustrations or photographs.

This is not to say building a circuit "ugly" style is inferior. As already mentioned, problems can occur in attempting to duplicate the circuit. However, for building a one-of-a-kind circuit, ugly can be a quick, cheap, dirty way to get it built and get it on the air. Over the years, I have had many QSOs with homebrew rigs built ugly. A couple were really ugly! The classic "Ugly Weekender" 40M receiver by Wes Hayward W7ZOI and Roger Hayward KA7EXM is a good example of a very nice performing rig built ugly style. It was featured in the 1992 Radio Amateur's Handbook and in the ARRL's book "QRP Power."



The AM detector and audio amplifier portion of a shortwave receiver built "ugly" style. The unused end-pins of the IC socket are soldered to the copper clad. The remaining socket pins are bent outward to make the connections.

There are few rules in building ugly. You simply "do your own thing" and get it working.

4. Conclusion

As most homebrewer's will tell you, there is nothing like the feeling of building a QRP rig and the thrill of having that first QSO with it. Whether you build ugly, a kit, or Manhattan style, QRPers will always be building their own equipment. This is why some of the QRP clubs and various vendors provide kits for building your own QRP transceiver. And, for those wishing to build a rig from scratch, this is why the QRP journals like the ***Homebrewer*** present as many construction articles as they can on the subject of homebrewing.

This article is intended for both the experienced builder and the new comer. If you've never built anything from scratch before, build a simple circuit using these techniques to "get your feet wet." AmQRP is committed to homebrewing. There will continue to be construction projects of different skill levels in future issues of the ***Homebrewer***.

In Part 2 **–** we'll continue with some of the construction practices employed in building circuits from scratch, including an emphasis on building with surface mount components, some various "hints and kinks," and a photo gallery of what others have built.

I am not a master builder of Manhattan. I never dreamed some of the stuff I've built would be featured in an article – or else I would have built them a little nicer! If you've built something from scratch, ugly or Manhattan, feel free to send me a photo or two to include in Part 2 to show what others have built, and how they built them. Likewise, if you have a construction hint or kink, send it to me and I'll gladly illustrate it for the next issue.

72, Paul Harden, NA5N
na5n@zianet.com

SMALL PORTABLE REGENERATIVE RECEIVER

(2003)

KLIK HIER VOOR DE NEDERLANDSE VERSIE

Small portable regenerative receiver, the reception outdoors is much better!

The small portable regenerative receiver.
The Big portable regenerative receiver is a success. It is simple and has an extreme low current consumption. The regenerative circuit would be very suitable for a small portable receiver if there were not so many controls and switches. So for this small version, the number of knobs and controls are reduced.
It is a nice receiver to take with you on holidays, there is always some place in your luggage. Battery use is so low that you do not need to take a spare battery.

Simplifications
It is only used for CW/SSB reception of radio amateurs. Volume control can be done by increasing the regenerative feedback. LF volume control is only necessary for AM reception so it is deleted.

Instead of the big air variable capacitor, a small mica type (50 pF) is used with less comfortable coarse tuning performance as a result. To compensate this compromise a little we take a very big tuning knob. Tuning an SSB station will be possible by experienced amateurs but may be difficult for beginners.

Only the 40, 30 and 20m bands are covered so that we need only one coil.

The disadvance of a normal on/off switch is that the receiver can easily be switched on during transport. Can be avoided if switching on/off is done by plugging in the headphone plug.

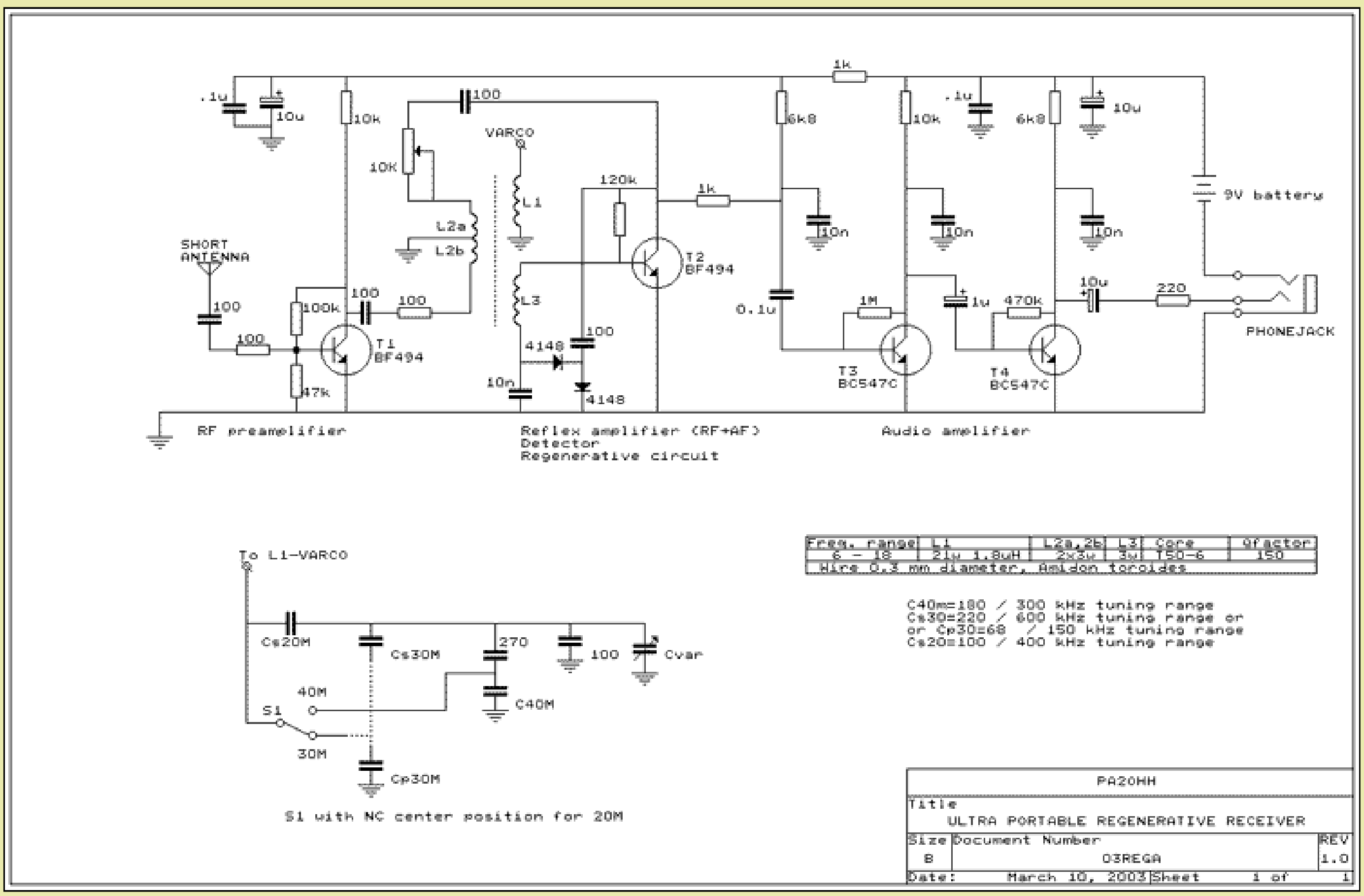
Battery use is very low, no voltage stabilizer is used. So a small 9 volt battery is good enough for hundreds of hours of listening.

The two earpieces of the headphones are connected in series instead of in parallel for more audio level. The original plug is replaced, both earpieces are connected in series between the center pin and ground. The remaining second contact is connected to ground for the on/off function.

What is left:

- Tuning (50 pF variable mica capacitor)
- Regenerative control
- One switch for 40/30/20 meters
- Headphone plug, also used as on/off switch
- Antenna connector for telescopic antenna, adjustable between 8 and 30 centimeters.

Schematic diagram



Circuit diagram of the small simplified ultra portable version of the regenerative receiver

[big diagram]

RF preamplifier
T1 is the RF preamplifier and also a buffer between the regenerative circuit and antenna.

Regenerative circuit, detector and reflex circuit
T2 is the most active transistor in this circuit. Firstly it act as an RF amplifier. The amplified signal is detected by two diodes and the detected audio is also amplified by T2. T2 is thus not only an RF amplifier but also an AF amplifier.
But T2 does more! It is also a regenerative circuit. Part of the RF output level is fed back to the input by the regenerative control potentiometer. Gain and selectivity increase enorm due to this regenerative process. For SSB and CW it should just

oscillate when maximum sensitivity is required. Increase the regeneration control to reduce the sensitivity.
Oscillation can be controlled very smoothly, due to the negative voltage from the detector to the base when oscillation starts. Gain of T2 will be reduced by this negative voltage.

Audio amplifier
T3 and T4 are BC547C transistors. Use the C type for more AF gain.

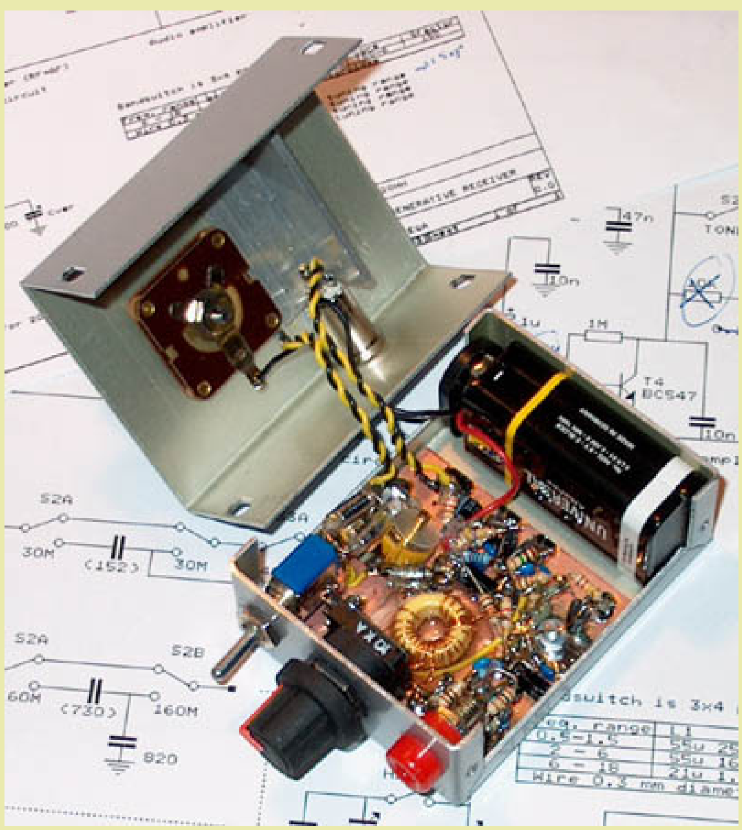
Tuning circuit
The band switches create a rather comfortable tuning range of each band. Fine tuning for SSB and CW can be done by varying the regenerative control a little or by moving your hand very close to the antenna.
Adjust the values of the inductances, capacitors and number of switches to your variable capacitor and desired bands, it is not so critical.
Of course you do not need to use toroides, all kinds of coils are suitable.
L1 is wound around the toroide, L3 is at the cold (ground) side of L1, L2a + L2b at center position of L1. If regeneration does not occur or if noisy oscillation only happens with the 10k regeneration control at maximum, reverse the connections of L3.

Antenna
The receiver is very sensitive and you should expect that a lot of weak DX stations can be heard. But that is not the case.
The receiver can only be used with short telescopic antennas, full size antenna's will cause a heavy overload of the receiver.

Interference by strong FM broadcast transmitters
On a few locations, interference was caused by strong FM broadcast transmitters. This could be solved by connecting a 10 pF capacitor between the base and emitter and another 10 pF capacitor between collector and emitter of T1, the RF amplifier transistor. And the 100 ohm resistor at the base of T1 is increased to 330 ohm.

Notes
Use BC547C transistors, the C types have the highest gain. The band switch has a center position for 20 meters whereby none of the contacts are connected. Both earpieces of the headphones are connected in series.

The receiver



Inside the receiver.

How to use the receiver
The receiver is only designed for SSB and CW reception, for AM reception you should add an AF potentiometer or at least a switched resistor in series with the 0.1 uF capacitor to the base of T3 (100k - 1M or so).
For weak SSB and CW signals it should just oscillate for maximum sensitivity. For stronger signals, increase the regeneration control (increase the amount of oscillation) to decrease the sensitivity.
Fine tuning can be done by varying the regenerative control a little.

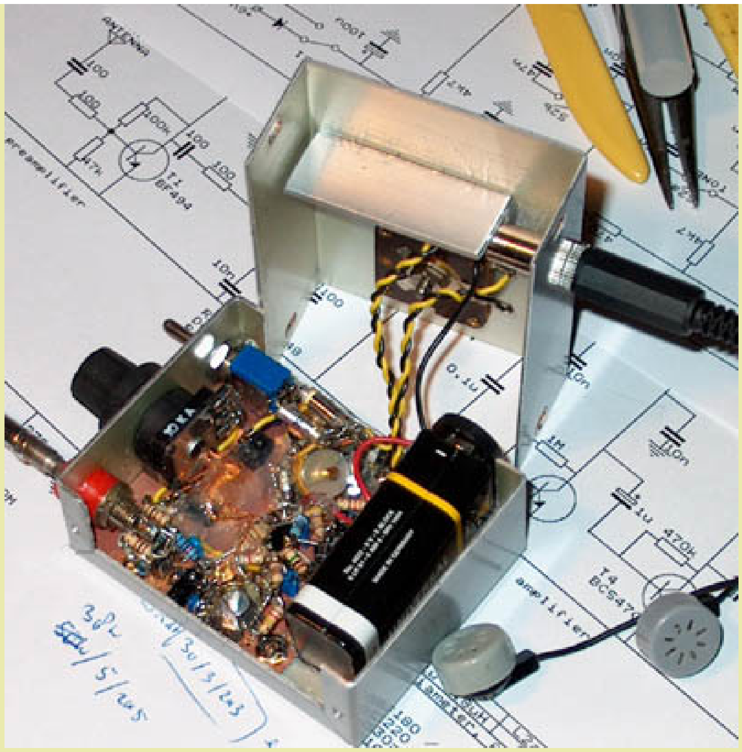
PERFORMANCE

Indeed, for AM broadcast stations the AF gain is too high. But SSB and CW signals from radio amateurs are not a problem at all! With the 30 centimeter telescopic antenna, whole Europe is already heard in SSB and CW on 40 and 30 meters with very comfortable signal levels. On 20 meters some USA stations are received, with good and easy readable signals, even in SSB. But do not compare it with a good receiver plus antenna, only stations of average strength can be heard. The receiver can be used indoors but the outdoors reception is much better.

The receiver during cold holidays

The small receiver sounds louder than the big one, perhaps because the earpieces are connected in series instead of in parallel or due to the higher battery voltage. I have not tested that yet.
Tuning is not so easy as with the big receiver. The big receiver has a very good variable capacitor that does 1.5 turn over its whole range, the small receiver 0.5 turn and it does not rotate so smoothly. Tuning of SSB signals will be very difficult for not so experienced amateurs, although fine tuning is possible by small changes of the regenerative control.
Conclusion: Except the somewhat difficult tuning (only for SSB, not for CW), the receiver is a very nice simple radio for SSB and CW with very low battery consumption. It is especially intended for portable use. For use in your shack or another fixed place, a bigger one with all the controls and a more comfortable tuning is advisable. If you want to make this small portable radio also suitable for AM reception, add an AF potentiometer.

TOROIDE REPLACED BY COIL ON PLASTIC ROD



Toroide replaced with coil on plastic piece of a potentiometer shaft.

The toroide problem

The frequency stability of the receiver was very sensitive for temperature. And that is strange because my first receiver with identical components is quite stable. The problem was a damaged toroide T50-6 (yellow one). As an experiment it was replaced by a coil on a plastic rod of 6 mm, a piece of the potentiometer shaft. Important is to keep a distance between the coil and the copper of at least 0.5 cm! L1 is about 25 to 30 wdg and L3 is 3 wdg. As an extra experiment, L2 is modified. L2a and L2b are replaced by one coil L2 of 6 wdg. The potentiometer and the 100 ohm resistor are connected together to one end of L2. The other end is connected to ground.

After replacement of the damaged toroide by the new coil, the frequency stability is much better. For best performance however, I would recommend the version with a good T50-6 toroide instead of the plastic rod. The coil with the toroide has a better Q-factor, needs less feedback for oscillation and is also less sensitive for metal parts. A good T50-6 toroide is not sensitive for temperature.

BACK TO INDEX PA2OHH

Passive Patch Antenna- Application Note

By: ***Ellie Manesh***
Applications Engineer
Abracon Corporation

The APAE Series is a selection of low profile PATCH ANTENNAS covering a wide range of frequency bands including GPS, GLONASS, SDARS, and RFID. These patch antennas offer small, low-profile, easy to mount PCB solutions; for systems requiring a flat & compact antenna.

The APAE Series is RHCP (Right Hand Circular Polarized) in order to be compatible with the propagated GPS signals. Other key characteristics include narrow bandwidth and high gain, to further improve system performance.

Positioning the patch on the end-product PCB

Electrical connection with the PCB is accomplished by soldering the silver pin through the hole on the PCB. Subsequently, the RF signal propagates through the PCB and excites the patch antenna.

During final board assembly, only the silver pin is soldered onto the PCB, by placing it through the hole and soldering it on the back side of the PCB. The adhesive tape is utilized to ensure solid positioning of the antenna on the PCB. It is not recommended to put the patch antenna through a standard reflow process.

The ideal position for the patch antenna is on top of the GPS receiver in the center of the printed circuit board. This technique eliminates the transmission line on the PCB between the input of the GPS receiver and the feed point on the antenna. Further, it limits the radiation plot distortion caused by the potential impedance mismatch.

Peak gain and center frequency may significantly vary depending on the position of the patch on the ground plane; while the VSWR and bandwidth is not affected by moving the patch on the ground plane.

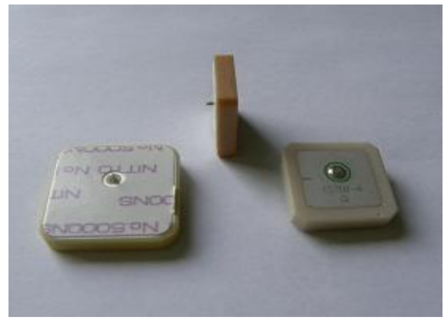


Figure (1); Front, Back, and Side View

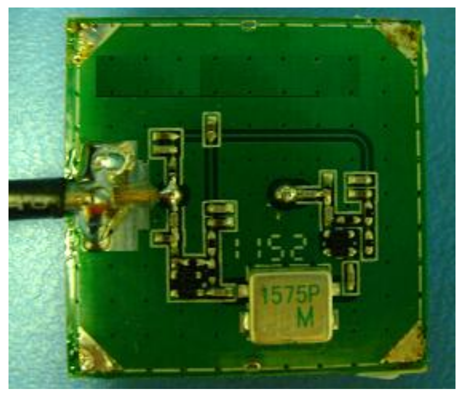


Figure (2); Patch Antenna Module (Back View)

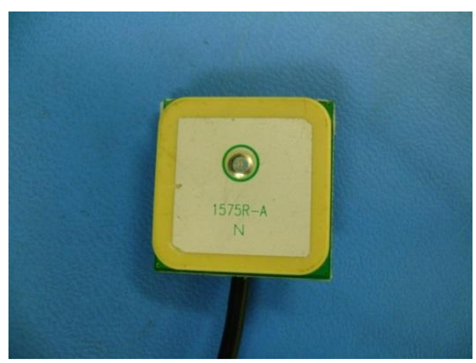


Figure (3); Patch Antenna Module (Top View)

It is recommended to mount the patch on the center of the ground plane. As we move the patch to the edge of the ground plane, the polarization which is ideally circular tends to become elliptical, which is not desired since the propagated GPS signals are circularly polarized.

Impedance Matching

The concept of VSWR (Voltage Standing Wave Ratio) is introduced as a measure of how well-matched an antenna is to the transmission line. If the impedance of the antenna does not match the impedance of the cable, a part of the signal will reflect from the antenna - back to the source.

Standard patch antennas are manufactured by matching to 50Ω input & output impedance on a well-defined Ground plane; on the manufacturers test fixture, in a controlled environment. In real world application when this antenna is placed on the end-product PCB, optimization is required. This optimization involves impedance matching in the end-product PCB to optimize the reflection coefficients. Further, if the end-product is encapsulated or has a metal cover, etc., this optimization accounts for the frequency shift of the patch in the end-product PCB.

Impedance matching may also involve placement of capacitors and/or inductors onto the PCB. It is also helpful to remember that the patch antenna impedance decreases as the feed location approaches the center.

A popular type of matching network is the PI-network, consisting of two shunt components with one series component in the middle. This method provides flexibility for impedance matching. Although only two components are used for matching the load to the source, PI-network allows putting the shunt component either before or after the series component.

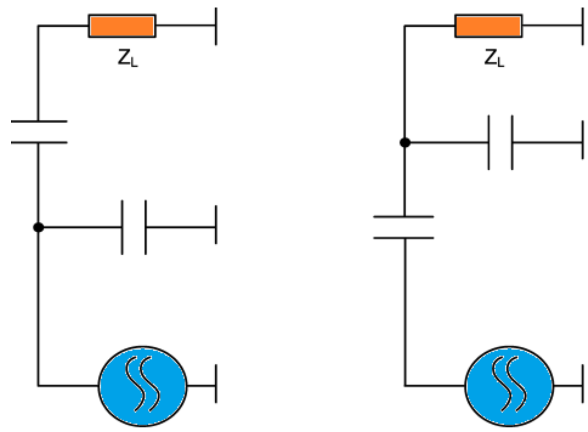


Figure (4): Two Possible Matching Networks

It is recommended to match the entire GPS band as close as possible to 50Ω and therefore, at least three frequency points have to be matched, as shown in figure (5).

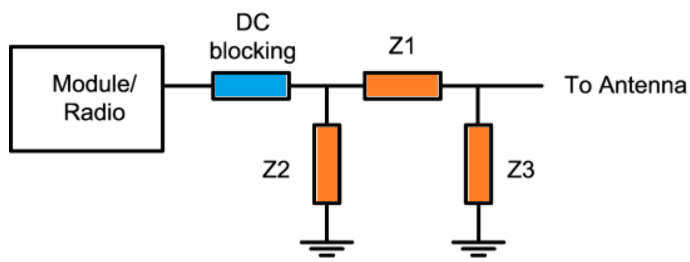
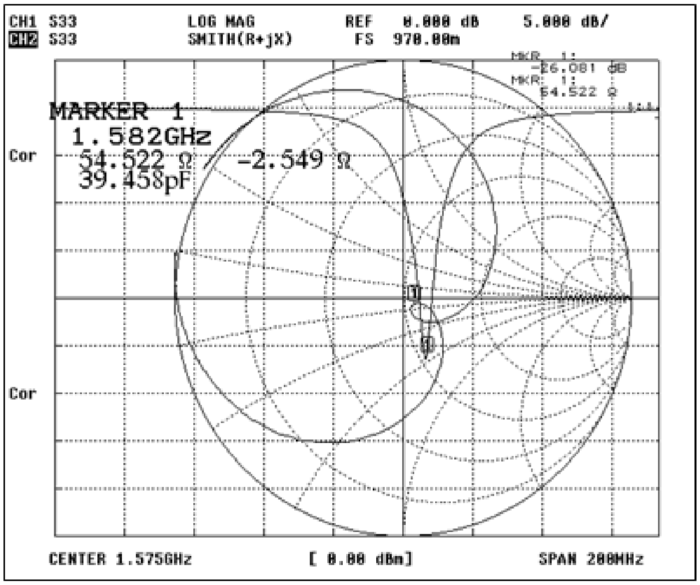


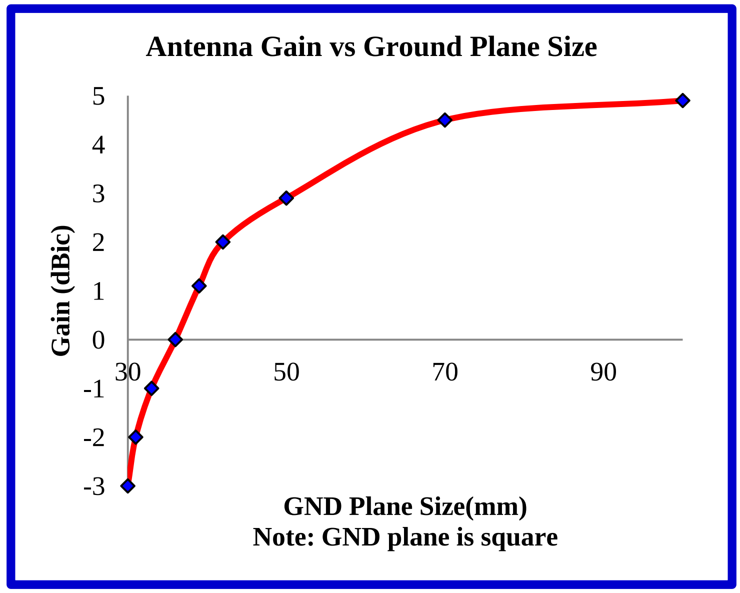
Figure (5): PI Network

Plot (1) depicts measured impedance for a GPS patch antenna in end-customer's application. In case of an exact match, the measured impedance is a real 50Ω with no imaginary part. In this example the impedance is 54.522Ω - j2.549Ω.

Passive Patch Antenna- Application Note



Plot (1): Smith Chart



Plot (2)

Ground Plane effect on Gain for APAE Series

Patch antenna is a passive component and therefore, its gain is defined as {antenna directivity times the radiation efficiency}. The antenna efficiency is defined as the ratio of the radiated power to the input power.

In general, the larger patches have higher gain than the smaller patches and even choosing a large ground plane for a small patch will not make its gain comparable to the gain of a larger patch. A GPS patch antenna has its highest gain when placed horizontally on a surface, facing the zenith since it can receive all propagated GPS signals. The gain will be lower if the patch is mounted on a surface that makes an angle with the horizon.

Typical peak gains for Abracon's patch antennas on standardized ground planes are as following.

Antenna Type	Patch Size	Gain
GPS	25x25x4mm	4.5dBic
Glonass	25x25x4mm	4.5dBic
GPS	25x25x2mm	4.3dBic
RFID	25x25x4mm	4.5dBic
SDARS	25x25x4mm	5.0dBic
GPS	20x20x4mm	3.8dBic
GPS	18x18x4mm	3.3dBic
GPS	18x18x2mm	1.4dBic
GPS	15x15x4mm	1.2dBic
Glonass	13x13x4mm	-2dBic
Glonass	13x13x5mm	-2dBic
GPS	13x13x4mm	0.6dBic

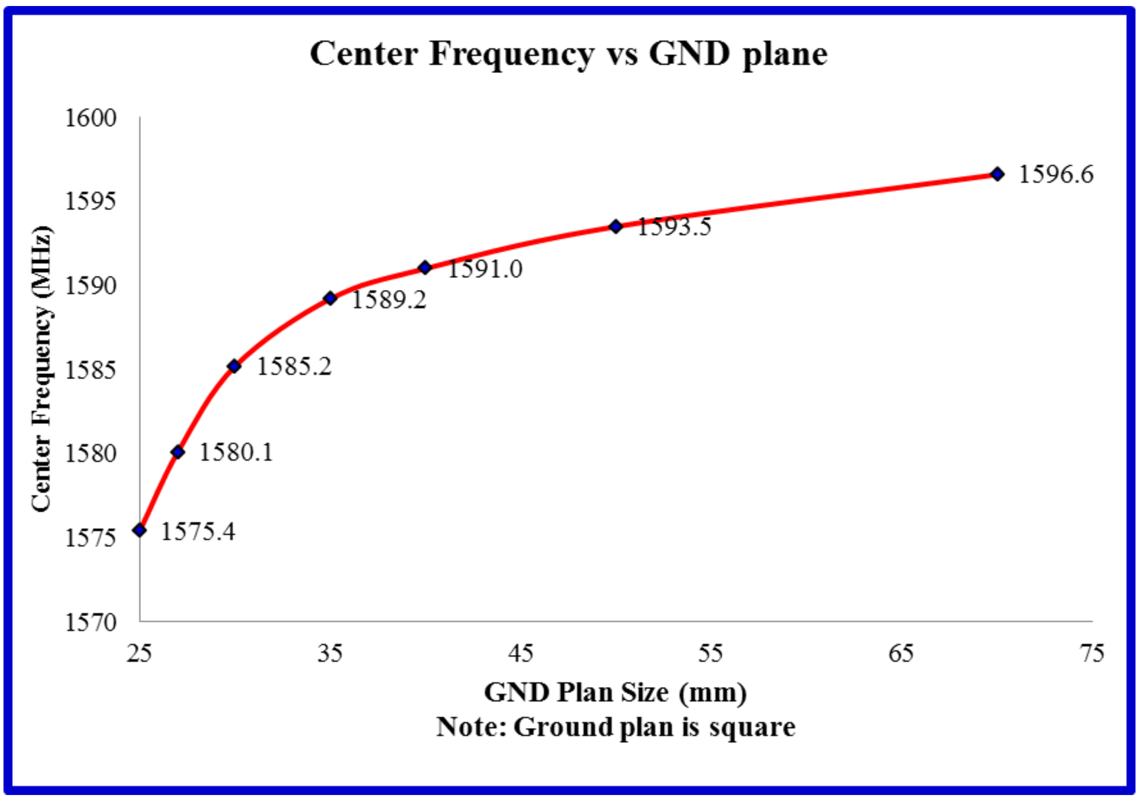
Ground Plane effect on Center Frequency

The center frequency of the patch antenna varies proportionally with the size of the ground plane and can be approximated by equation (1):

$$fc \approx \frac{c}{2L\sqrt{\varepsilon_r}} = \frac{1}{2L\sqrt{\varepsilon_o \varepsilon_r \mu_o}} \qquad \textbf{(1)}$$

L :	Size of the Ground Plane
C :	Speed of the electromagnetic wave
εo:	The Vacuum Permittivity 8.854187817* 10-12 F/m
εr:	Relative Permittivity of the Dielectric Material
µ0:	1/(c2ε0)=1/(299,792,4582(8.854*10-12)) =1.26x10-7 H/m

Application environment such as size of the ground plane, proximity to other components and a dome will affect stated performance. Fine tuning of the patch antenna is required in end-customer's application in order to achieve the desired center frequency.



Plot (3)

Tuning (Optimization)

Antenna's performance is affected by the environment such as its proximity to other components or to the dome. Almost in all cases, tuning is required after the patch antenna is mounted in the end-application.

There are several methods to tune the antenna such as moving the feed point, changing the shape of the top silver electrode, and scratching the corners or sides of the top silver plate.

Per Abracon's standard procedure, customers purchase standard products from our distribution channel and try them in their application. Almost in all cases, the patch needs to be tuned to account for overall environmental effects in the end-application. At this point, our customer sends us their PCB, three samples of patch antenna, and any additional coverage (such as Dome, cover, etc.) for fine tuning. One patch is tuned exactly to the desired frequency, one patch to a slightly higher, and one patch to a slightly lower frequency.

Figure (7): Optimized Patch

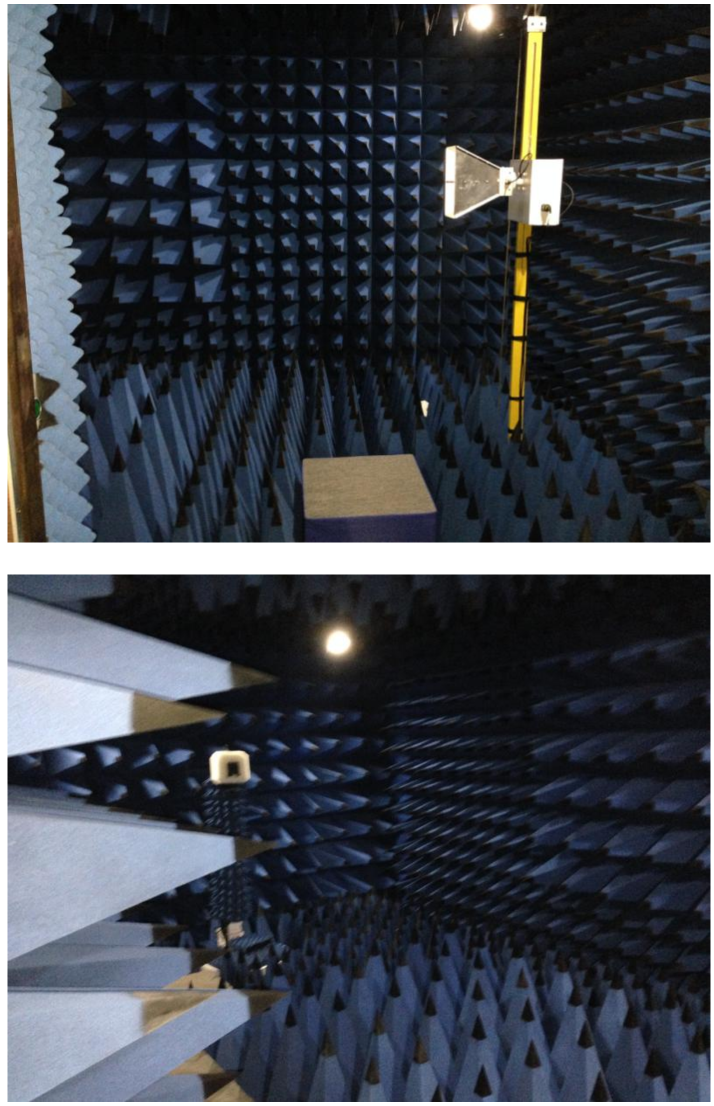


Figure (6): Radiation Chamber

Test data is provided for before and after tuning for comparison purposes. Once the customer receives the tuned patches, these devices are tested in the end-application and if the performance is deemed satisfactory, a custom part number is issued for the patch with the best performance {from the (3) supplied samples}. A custom data sheet is created based on the tuning results for mass production. Subsequent orders are manufactured in accordance with the custom data sheet.

Radiation Pattern

Patch antenna's radiation pattern shows that the antenna radiates more power in a certain direction than other directions. This characteristic in antennas is called directivity which is measured in dB.

For an ideal patch antenna, all radiation is received in one half of the hemisphere which means 3dB directivity. In this scenario, all radiation is towards the front and no radiation is towards the back of the antenna.

However, in real world applications, a portion of the radiation is towards the back of the antenna. The front to back ratio is very much contingent upon the size and shape of the ground plane.

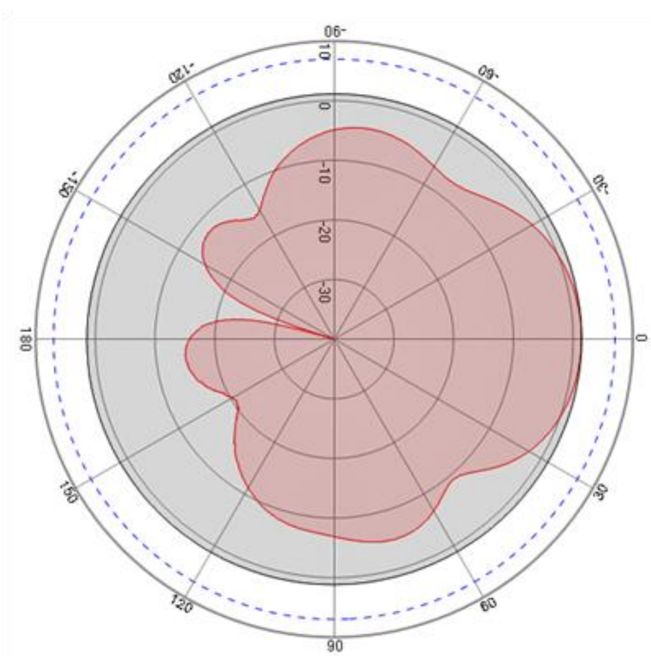
A patch antenna has a maximum directivity in the direction perpendicular to the patch. This directivity decreases as the patch is moved towards the horizon. The 3 dB bandwidth is twice the angle of the maximum directivity. In another words, the 3dB bandwidth is where the directivity has dropped by 3dB; with respect to the maximum directivity.

As part of the optimization service, Abracon provides radiation plot for each patch antenna, before and after the tuning process, for comparison purposes.

Impact of Adjacent Antennas

GPS signal is of low power and is vulnerable to interference from higher power cellular or Wi-Fi radiation in the end-application. Therefore, the GPS antenna should be placed as far away as possible from other antennas, such as Bluetooth or WWAN, in the end-application.

In order to make sure that the signals from other antennas don't interfere with the GPS signal, validation is conducted by sending a signal in one antenna and measuring the power of the signal at the other antenna. There should be a 10dB or more difference between the transmitted and the received signal. The easiest technique is to continue moving the two antennas farther away from each other and keep measuring the sent and received signals; until the desired isolation is achieved.



Plot (4): Radiation Pattern

Impact of surrounding Components

Performance of patch antennas is affected by proximity of adjacent components, housing, display, etc. These surrounding components influence the center frequency of the antenna, as well as, cause variation in the radiation pattern. It is recommended that a clearance of 4~10mm is maintained in all directions from adjacent components including housing; in order to ensure maximum efficiency from the patch antenna. The cable between the feed-line and the power source should not be bent more than 30 degrees and should be routed away from any noisy components such as Digital Integrated Circuits.

If Radom is used to protect the patch antenna and the LNA, frequency will be shifted down. If the PCB material thickness is 1 mm and the distance to the patch is 8 mm, frequency will shift down approximately 2.0MHz. It is reasonable to expect a center frequency shift of 1 ~ 4 MHz, depending on this distance.

Design Recommendation

The most important point to consider when drafting a design containing a GPS passive patch is that the GPS signal is below the noise floor. We are surrounded by digital noise and the best solution to avoid it is isolation.

The first stage in the GPS receiver is the LNA. A low-noise power source is required for LNA to properly function.

To improve noise isolation, reactive filtering using an inductor, a bead and/or a capacitor is recommended between the LNA and the bias stage.

A GPS grade **TCXO** with an initial tolerance of no worse than ±2.5 ppm is required for fast time-to-first-fix (TTFF).

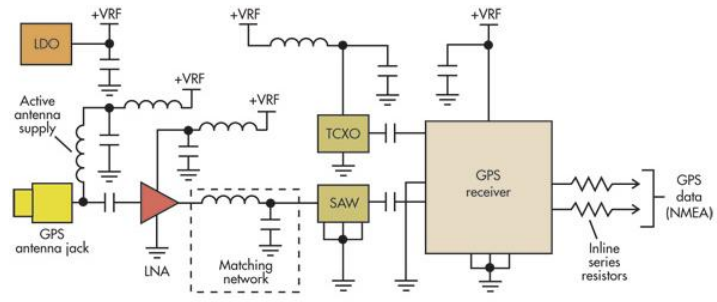


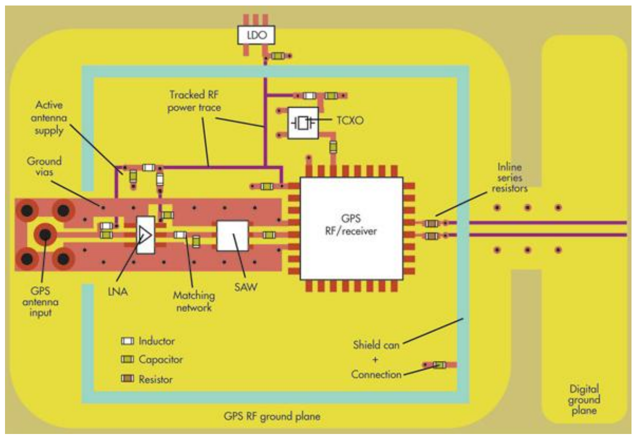
Figure (8): Schematic of a Typical GPS receiver

For proper GPS operation, much tighter stability TCXO's are needed having ~1ppb short term stability. Thermal transients due to heat generating components like PA or LNA could have profound impact on the short term TCXO stability. Additionally, switching components like regulators can also influence the TCXO performance.

To create some degree of isolation, TCXO's are shielded and thermal isolation is achieved with careful PCB design and physical placement of the TCXO, away from the aforementioned components.

SAW BandPass filters can be employed to further improve the overall system performance. Abracon also offers GPS frequency **SAW BPF's** in 1.4x1.1mm, 2.0x1.6mm, 2.5x2.0mm and 3.0x3.0mm footprints.

Figure (9): Layout of a simplified GPS-receiver



Noise Control

In order to optimize noise suppression, additional considerations need to be taken. For instance, some frequencies are not compatible with a GPS receiver. Common interfering frequencies are 4 MHz and 19.2 MHz (1575.42 MHz is a multiple of 19.2MHz). It is suggested to change the reference frequency to 24, 25, or 26 MHz.

In order to control impedance and reduce transients, calculate the capacitance of the inputs and then insert a resistor in series to set the edge rate (Figure 10). To calculate the edge rate, either a charging curve is used or the value is approximated using Equation (2) below, representing a 10%/90% switching point.

$R = 3t/C$ …………. (**2**)

As an example, if 10%/90% switching point is needed with 10-ns rise/fall time for a clock line at 10 MHz and a IC input load capacitance of 10pF:

$R = 3t/C$

$= 3x10^{-8} / (1x10^{-11})$

$= 3\ k\Omega$

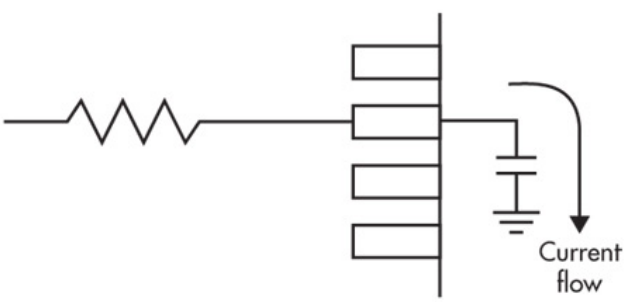


Figure (10): Insert a resistor in series to set the edge rate.

Customization

For customization of a standard Abracon Patch Antenna, in order to optimize in-circuit performance; please contact us at:

tech-support@abracon.com

Stocking Distributors' Links:

- **Digikey**
- **Mouser**

Author:

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- Jeff Wilson (Electronic Design, Aug-2011). Adding a GPS Chipset to your next design is easy
- Texas Instruments, Application Report March-2008; AN-1811 Bluetooth Antenna Design

United States Patent [19]

Sion

[11] **3,902,108**

[45] **Aug. 26, 1975**

[54] **VOLTAGE MULTIPLIER**

[76] Inventor: **Daniel Sion,** 19 Ave. Dubonnet, 92401-Courbevoie, France

[22] Filed: **Jan. 30, 1974**

[21] Appl. No.: **437,797**

[30] **Foreign Application Priority Data**

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Feb. 27, 1973	France	73.07427

[52] **U.S. Cl.** **321/15**

[51] **Int. Cl.²** **H02M 7/00**

[58] **Field of Search** 321/15

[56] **References Cited**

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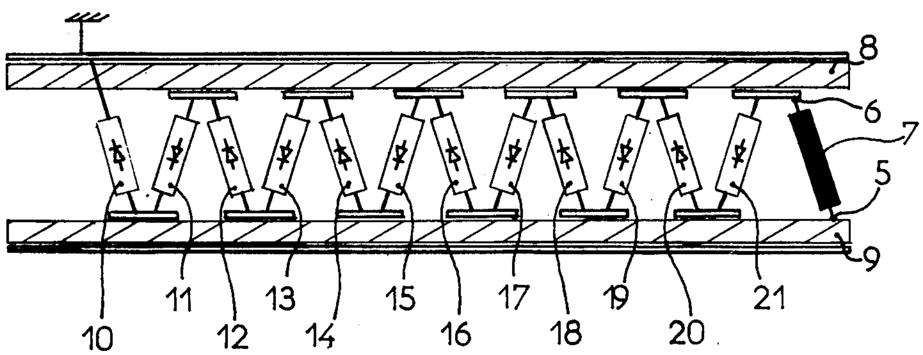
Primary Examiner—R. N. Envall, Jr.
Attorney, Agent, or Firm—Lee C. Robinson, Jr.

[57] **ABSTRACT**

A multi-stage cascade voltage-multiplier device which includes electric condensers and diodes of the composite type comprising an assembly of elementary diodes. Each of the composite diodes is disposed between two conductive surfaces and is oriented substantially perpendicular to the surfaces at an adequate distance therefrom such that all of the elementary diodes are subjected to substantially the same instantaneous reverse voltage and undue breakdown of the diodes is prevented. In some embodiments the voltage-multiplier device is of the parallel-series type and is associated with a direct-current high-tension generator with at least the multiplier device incorporated in the barrel of an electrostatic projection gun.

10 Claims, 9 Drawing Figures



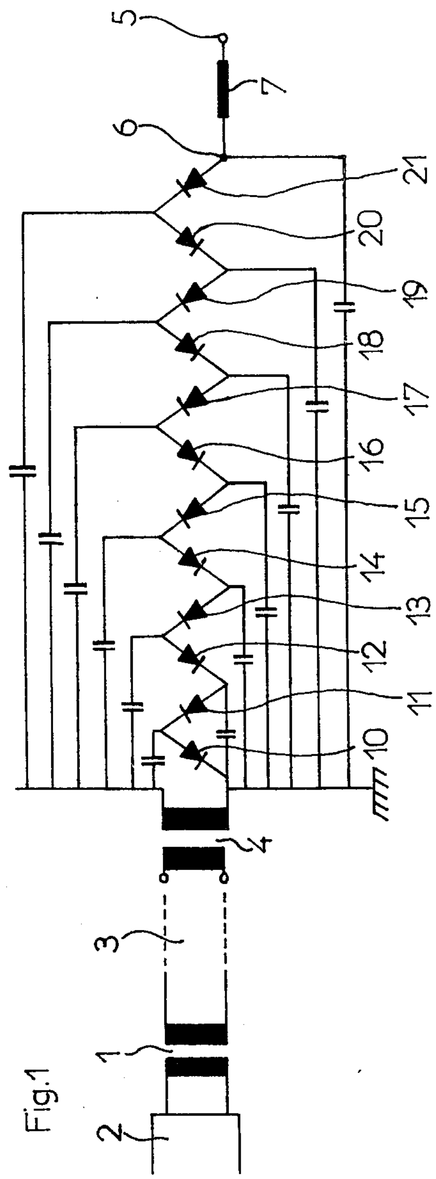

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Fig.1

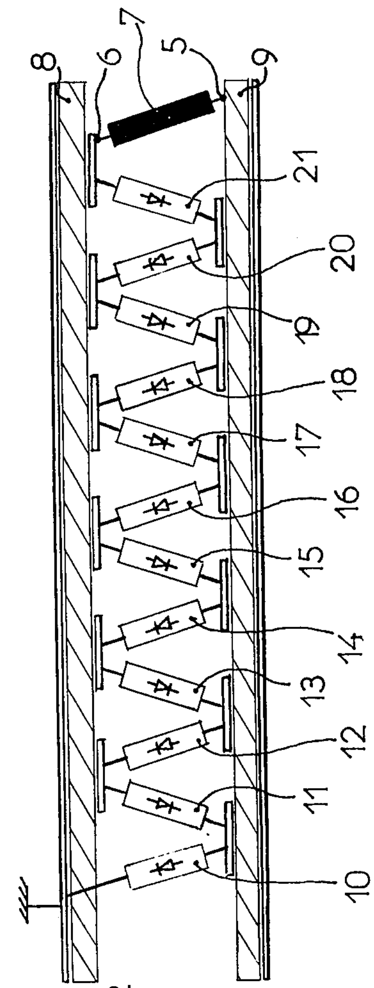
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Fig. 2

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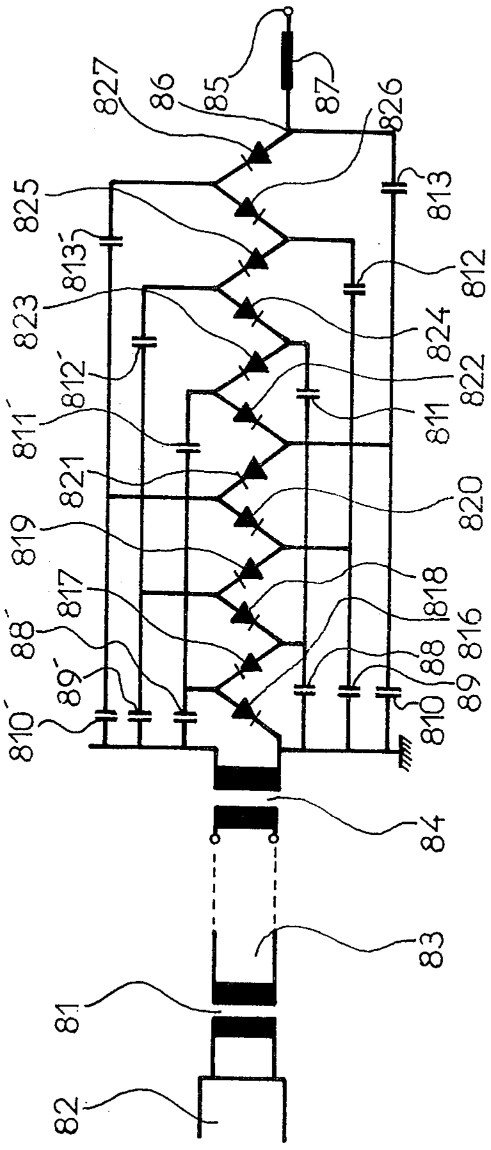


Fig.3a

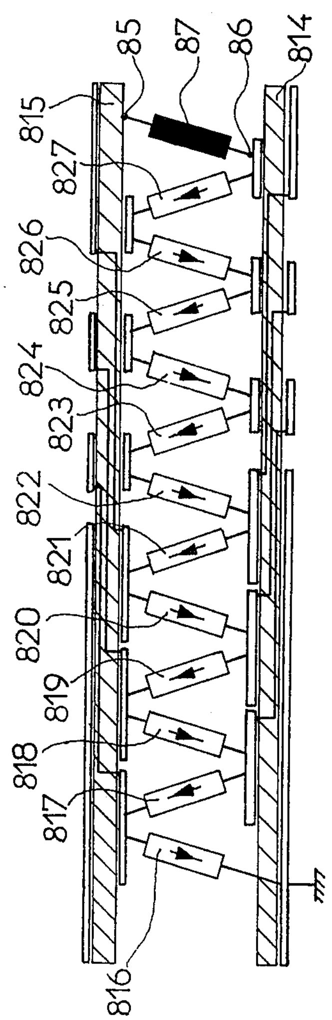


Fig.3b

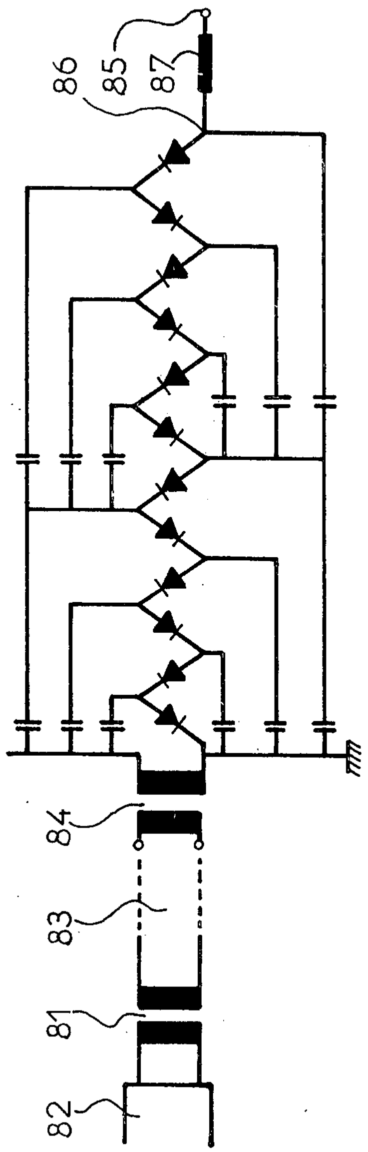


Fig. 4a

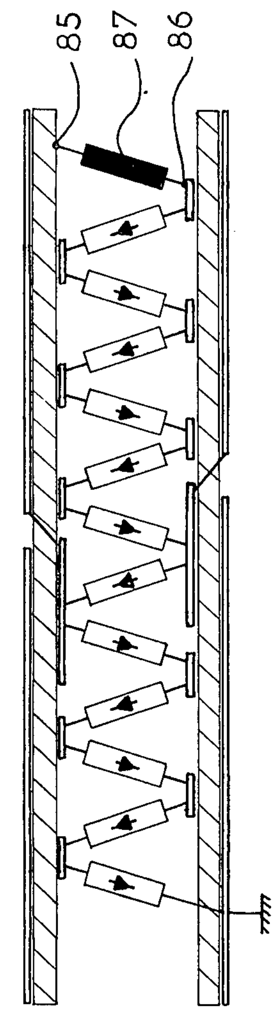


Fig. 4b

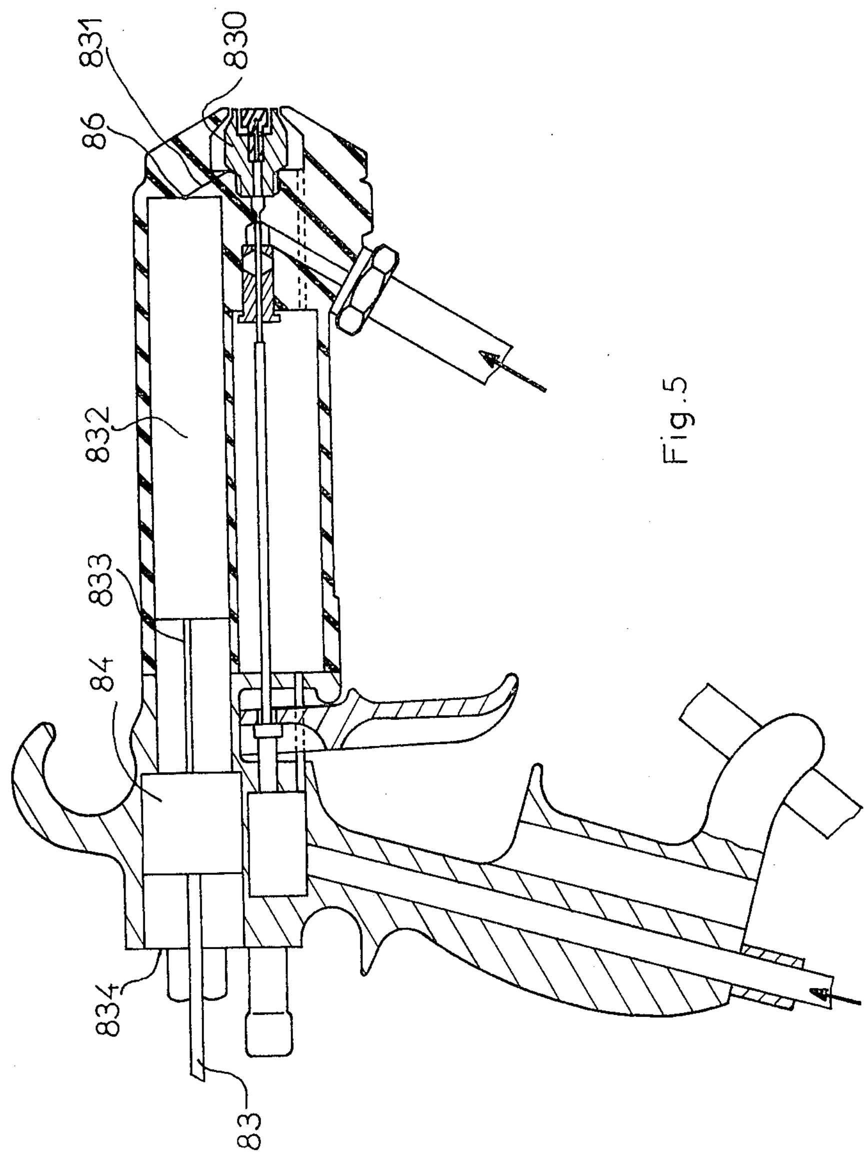


Fig.5

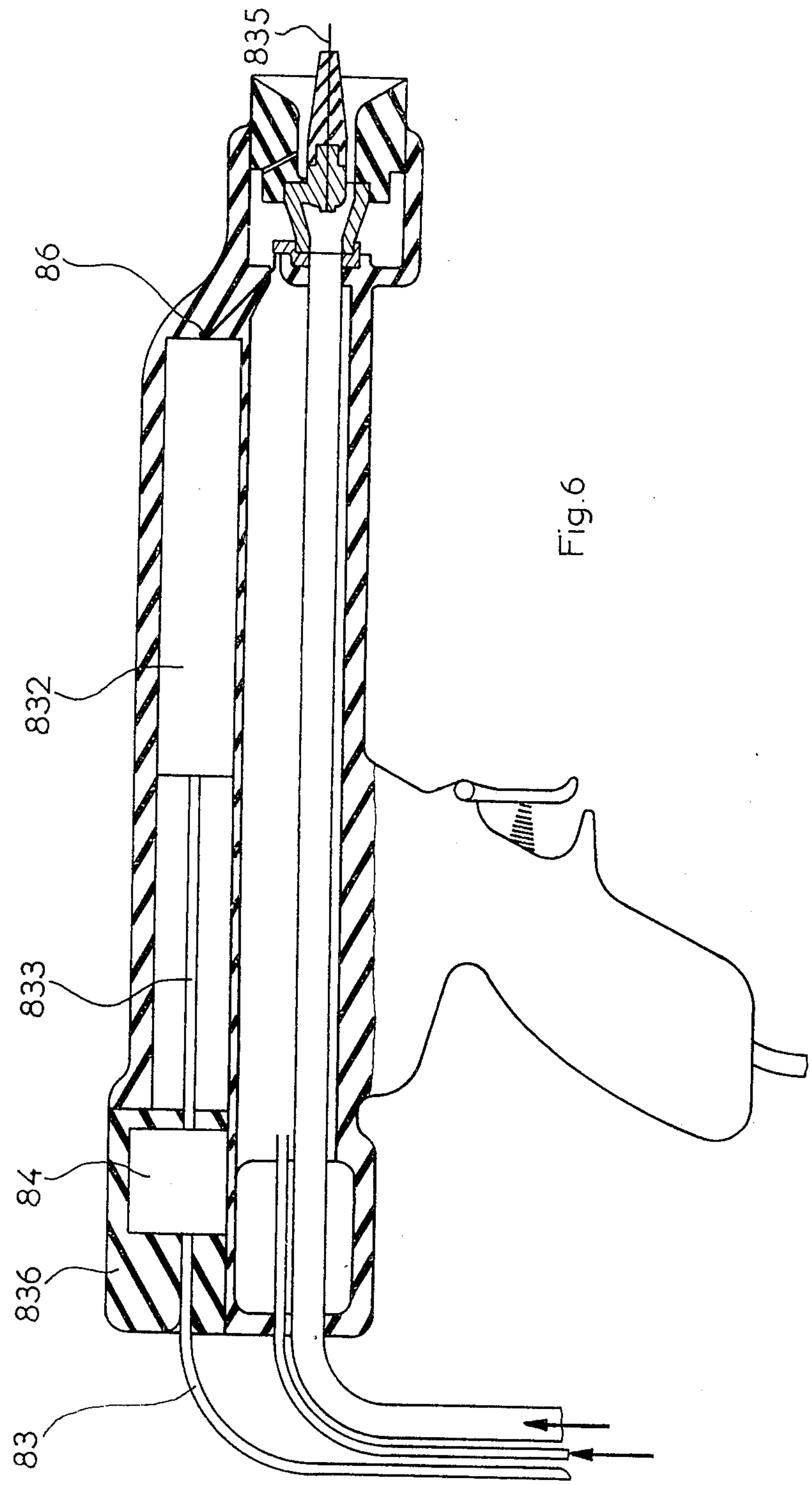


Fig.6

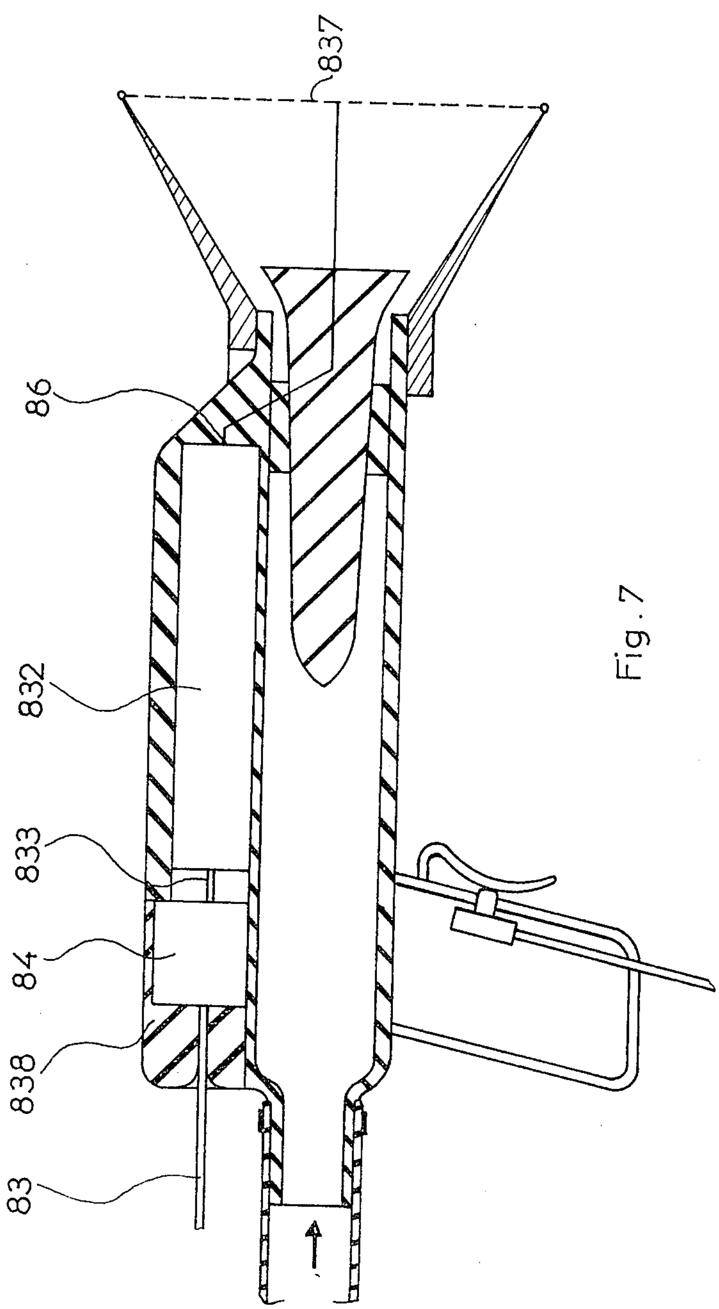


Fig. 7

VOLTAGE MULTIPLIER

BACKGROUND OF THE INVENTION

The present invention relates to multi-stage cascade voltage-multiplying devices and more particularly to such devices for use with direct-current high-tension generators.

Voltage multipliers of this kind commonly include a succession of rectifier stages, with diodes and condensers, and are either of the series type, following the conventional Greinacher connection, the parallel type, or the hybrid type, these different kinds of known connections being described for example on page 1,081 of the Dutch Review "Bedrijf en Techniek" of June 10, 1971.

A series connection is characterized by the fact that each of the capacities relative to a stage of order N is referenced with respect to the capacitance of the stage of order $(N - 1)$; a parallel connection is characterized by the fact that the capacities of each of the stages are referenced in turn with respect to one and the other of the alternating input terminals of the cascade multiplier; and a hybrid connection is characterized by the fact that the capacities of each stage are each referenced with respect to a selected capacitance of a preceding stage.

In situations in which it is desired to obtain a very high output voltage, for example of the order ot 60 to 80 kV, as is the case for high-tension generators intended to supply such equipment as electrostatic painting or powdering guns, the diodes of the device should be capable of withstanding the instantaneous reverse voltage utilized. Such diodes frequently comprise a compact assembly having a series of elementary diodes, the number of which may be as high as several hundred.

Heretofore, the connection in series of these elementary diodes has exhibited a serious drawback. If in theory each of the elementary diodes must withstand an instantaneous reverse voltage equal to a value inversely proportional to the number of diodes of the total instantaneous reverse voltage, in reality this is unfortunately not always the case. For example, if all the elementary diodes in series are distributed over an equipotential surface, only the first and last of the elementary diodes will have an instantaneous inverse potential difference at their terminals, the instantaneous reverse voltage will be divided only between these two elementary diodes, and they will therefore be subjected to a reverse voltage very much greater than that which they can withstand.

It has therefore been frequently found that the diodes employed in prior voltage multiplier circuits for apparatus supplying high voltages had a very short life.

SUMMARY

The method of construction of voltage multipliers according to the invention enables this drawback to be overcome. By this means, in fact, each elementary diode forming part of a combined diode is subjected to an instantaneous reverse voltage which is approximately the same. The arrangement is such that the various diodes in the cascade are prevented from becoming damaged after a short working life.

In several important embodiments of the invention, each of the combination diodes forming the cascade is arranged between two comparatively large conductive surfaces. The diodes are located sufficiently from these surfaces, and in a manner either perpendicular or slightly oblique with respect to the surfaces, that the instantaneous electric field along the diode is approximately constant. There is thus obtained an instantaneous potential difference which varies uniformly along the combination diode, and in consequence a potential difference at the terminals of each of the elementary diodes, which is substantially identical for each elementary diode at every instant.

Certain advantageous embodiments of the invention utilize cascade voltage multipliers in a novel design for electrostatic projectors, such as projectors for liquid, powder or fibers. The projectors are of the type in which the cascade voltage multiplier is associated with a hightension generator for supplying the charge electrode of the projector and is incorporated in the gun portion of the projector.

Electrostatic projectors, such as for example fixed or manual guns for electrostatic painting, powdering or flocking, generally employ a separate high-tension generator connected to the projector by a high-tension cable. a high-tension voltage is delivered to the projector and can vary within the range of between about 30 and 150 kV. In order to connect the generator to the gun, it has heretofore been necessary to utilize comparatively heavy, bulky and relatively rigid cables, with the result that the handling properties of the gun were adversely affected to a substantial degree.

These difficulties were of particular moment for manual electrostatic projection guns. In an attempt to resolve the problem, it has been proposed, in accordance with published German Patent Application No. 1,039,894 and French Pat. No. 2,051,226, to incorporate all or part of the high-tension generator in the gun itself.

An electronic high-tension generator for an electrostatic spraying gun, for example, generally comprises a DC-AC converter having at its output an alternating voltage of a value of a few multiples of 10 volts and a frequency of several multiples of 10 kilohertz. This DC-AC converter is followed by a voltage step-up transformer which produces an alternating voltage of a few kV, supplying in turn a conventional cascade multiplier comprising diodes and condensers.

The early attempts to incorporate at least part of the high-tension generator in the electrostatic projection gun commonly included the location of a cascade multiplier of the series or Greinacher connection type in the barrel of the gun. The utilization of such a series type cascade, however, often resulted in considerable production difficulties. As an illustration, the capacitances necessitated by this type of cascade are of relatively high value, going from a few multiples of ten to several hundred pF. To achieve these high capacitances by the convenient technique of metallizing the faces of a printed circuit plate, the dimensions of the plate would be too large to be capable of incorporation in the barrel of the gun. In consequence, it was heretofore necessary to use commercially available condensers in the cascade circuit. The mounting of such a cascade having sufficiently small dimensions for it to be incorporated in the barrel of a gun is very awkward, however, and therefore the production cost is high.

In addition, the unit capacities of the cascade Greinacher connection commonly are of the order of about 50 pF, and it is difficult or even impossible at the present time to find available in commerce condensers hav-

ing such a low value which at the same time exhibit a sufficiently high breakdown voltage. Accordingly, the circuits often were designed with capacitances having a value of the order of 10 times that which was actually needed.

Now, as is well known in the technique of electrostatic projection, if the accumulated energy is sufficiently high it can give rise to a dangerous spark which may result in a fire or explosion in the projection cabin. With such unnecessarily high capacitances, this risk of fire or explosion became needlessly increased.

It was therefore proposed to utilize another type of cascade device, known in the art as a "parallel cascade multiplier" or "parallel adding device." In this latter type of cascade, the capacitance of each of the stages is no longer referenced with respect to the corresponding capacitance of the preceding stage, as is the case in a series adding device, but is referenced with respect to one of the two input terminals of the cascade device. A parallel adding device of this known type is shown diagrammatically, for example, in FIG. 6*a*, page 1,081, of the Dutch Review "Bedrijf en Techniek" referred to above.

The capacitances necessary for a parallel cascade device are definitely smaller than those required for a series cascade device of equivalent performance characteristics. For example, it has been calculated that for a Greinacher cascade with six stages having a unit capacitance of 50 pF, the theoretical unit capacitance of the corresponding parallel connection was only 3.6 pF. The actual unit capacitance utilized for the construction of the circuit will obviously be greater than 3.6 pF because of the stray capacitances, but in practice it will remain very low.

These low unit capacitances are produced by metallization of the faces of a plate for a printed circuit, in a particularly simple form, since the capacitances of the fixed column and also those of the oscillating column are all referenced respectively to the same point. The diodes also may be easily arranged in the manner previously described, which ensures that they have a long life.

The utilization of parallel adding devices for incorporation in the barrel of an electrostatic projection gun is not, however, free from certain disadvantages. The printed circuit plates readily available commercially have a thickness defined by a standard (e.g., 1.6 mm.) and are not readily able to withstand excessive voltages. It is generally accepted that the maximum voltage which can be withstood by a plate of this thickness is of the order of about 40 kV. Now, in the case of most guns it is desired to have a voltage of the order of 60 to 80 kV for manual guns and a voltage of the order of 100 to 150 kV for guns provided on automatic installations.

In a parallel adding device, each of the condensers is subjected at its terminals to the total voltage of the corresponding stage, so that, by the use of a standard printed circuit plate with a thickness of 1.6 mm., voltages greater than about 40 kV should not be used. This may be alleviated, to some extent, by employing a printed circuit plate having a thickness which increases with the stages, but the resulting structure is unnecessarily complicated and production costs are increased.

Another possible solution is the use of a printed circuit plate of constant thickness but over-dimensioned. Here again, however, the arrangement is not ideal,

among other reasons because it increased the weight of the cascade device and also its dimensions. Furthermore, the energy accumulated in the last condensers of the device is comparatively high because of the high mean voltage at the terminals. It has been calculated that the accumulated energy in a parallel cascade of n stages was of the same order of magnitude as that accumulated in a Greinacher cascade of n stages, the increase in voltage at the terminals of the condensers in the parallel cascade compensating approximately for the reduction in the value of the condensers as compared with those in the Greinacher cascade. There is thus little progress with respect to a reduction of the discharge energy in the event of a spark, when passing from the optimum Greinacher cascade to the parallel cascade.

The electrostatic projector with a cascade incorporated in the barrel according to a preferred embodiment of the invention does not possess the disadvantages of the electrostatic projectors with built-in cascades referred to above. In fact, the invention makes it possible to produce the capacitors of the cascade on a printed circuit of small thickness, this thickness being constant, with the result that there is a very substantial reduction in the discharge energy of the cascade in the event of a spark.

In accordance with certain advantageous embodiments of the invention, a form of cascade of the hybrid type, that is to say parallel-series cascade, is built into the barrel of the electrostatic projection gun.

Examples of hybrid cascades of this type are shown diagrammatically in FIG. 7 on page 1,081 of the Dutch Review "Bedrijf en Techniek" referred to above.

The invention will be more clearly understood by means of the description which follows below relating to a few examples of construction, reference being made to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1 and 2 show respectively an electric diagram and an assembly diagram according to an illustrative embodiment of the invention, depicting a cascade of the parallel type intended to be employed for the supply of high-tension current to an electrostatic painting, powdering or flocking gun, the cascade being miniaturized in such manner that it can easily be incorporated in the barrel of the gun.

FIGS. 3*a* and 3*b* represent respectively an electrical diagram and an assembly diagram according to another illustrative embodiment of the invention, depicting a cascade of the hybrid type intended to be built in to an electrostatic projection gun.

FIGS. 4*a* and 4*b* represent respectively an electrical diagram and an assembly diagram of still another type of hybrid cascade intended to be incorporated in an electrostatic projection gun in accordance with a further illustrative embodiment of the invention.

FIG. 5 shows diagrammatically a manual electrostatic painting gun incorporating a hybrid cascade of the type illustrated in FIGS. 3*a* and 3*b*.

FIG. 6 shows diagrammatically a manual electrostatic powdering gun incorporating a hybrid cascade of the type illustrated in FIGS. 3*a* and 3*b*.

FIG. 7 shows diagrammatically a manual electrostatic flocking gun incorporating a hybrid cascade of the type illustrated in FIGS. 3*a* and 3*b*.

DESCRIPTION OF CERTAIN PREFERRED EMBODIMENTS

In FIG. **1** the reference **1** indicates the output transformer of a DC-AC converter **2** operating at an illustrative frequency of 30 kHz. A voltage of about 20 volts is taken from the secondary of the transformer **1** and is delivered by means of a cable **3** to a transformer **4.** The transformer **4** is located in the body of an electrostatic projection gun and supplies an output voltage of about 5 kV at its secondary.

A parallel cascade is provided at the terminals of the transformer **4.** The cascade comprises six stages and provides at its output **5** a direct current high-tension voltage having a value sufficient to supply the charging electrode of the electrostatic spraying gun. The output **5** is connected to the point of highest voltage **6** of the cascade through the intermediary of a resistance **7** having a value of a few megohms, for example 10 megohms, serving to protect the generator for the gun.

FIG. **2** shows a form of construction of the cascade of FIG. **1.** Each of the capacitors in the cascade is produced by metallization of each of the faces of a pair of flat insulaing plates **8** and **9.** These plates are similar to the plates used for printed circuits, and each plate illustratively is formed from a sheet of epoxy resin having a thickness of 2.6 mm., a length of 14 cm., and a width of about 4 cm.

Electrically connected between the plates **8** and **9** are a series of combination diodes **10 – 21.** With the object of preventing the elementary diodes which constitute each of the combination diodes **10 – 21** from being subjected to reverse voltages which are not substantially identical in instantaneous value, the plates **8** and **9** are placed one above the other in parallel planes. The combination diodes **10 – 21** are placed to provide current flow in a direction perpendicular or slightly oblique with reference to these planes, so that each of the diodes is located in a zone in which the instantaneous electric field is approximately constant. For that purpose, the diodes also are positioned in spaced relationship with the edges of the metallized plates. The position of each diode with respect to the edges of the plates is particularly important in the production of a cascade multiplier according to the invention.

A convenient numerical estimation of the positions to be adopted for these diodes may be obtained by considering the minimum distance in a plane orthogonal to the diodes from the outer surface of each diode to the edge of the adjacent plate and then estimating the ratio R between this minimum distance and the mean distance between the plates.

For a ratio R greater than or equal to 1, the effect desired by the present invention is particularly well obtained. The effect is less pronounced as the ratio R diminishes. It is still fairly satisfactory in the vicinity of a ratio R equal to 0.5, but it is nonexistant for a ratio R of zero or of the order of 0.1 to 0.2. In the assembly shown diagrammatically in FIG. **2,** the distance between the plates **8** and **9** is of the same order of magnitude as the length of the combination diodes, namely about 2 cm.

Although the facing surfaces of the plates **8** and **9** are flat, it is apparent that they may have substantially any other shape, such as incurved shape, without departing from the scope of the invention, provided that the position and the general direction of each of the combination or compound diodes correspond to a position and a direction in which the instantaneous electric field is approximately constant.

In FIG. 3a the reference **81** indicates the output transformer of a DC-AC converter **82** operating at an illustrative frequency of about 30 kHz. A voltage of about 20 volts is collected from the secondary of the transformer **81** and is delivered by a flexible lightweight cable **83** to a small transformer **84.** The transformer **84** is located in the body of the gun and delivers to its secondary an output voltage of about 5 kV and a frequency of about 30 kHz.

A cascade of the hybrid or parallel-series type is connected across the terminals of the secondary of the transformer **84.** This cascade includes six stages and provides at its output terminal **85** a direct-current high-tension voltage, illustratively about 60 kV, which is sufficient to supply the high-tension electrode of the electrostatic projection gun.

The output terminal **85** is connected to the point **86** of the highest voltage of the cascade through the intermediary of a resistor **87.** The resistance of the resistor **87** is of the order of a few megohms and serves to protect the generator.

The circuit design of the hybrid cascade according to FIG. 3*a* is such that none of the condensers in the cascade is subjected to a voltage exceeding about 30 kV. It will be understood that a hybrid cascade is characterized by the fact that the capacitances of each stage are referenced with respect to a capacitance chosen from the same column but in a preceding stage.

In order that the voltage be maintained below about 30kV, and taking account of the fact that the alternating voltage delivered to the secondary of the transformer **84** has an amplitude of 5 kV, the assembly is made in the following manner: the condensers **88, 88′, 89. 89′, 810** and **810′** of the first three stages of the cascade are referenced with respect to the input terminals of the cascade, that is, with respect to the output terminals of the secondary of the transformer **84.** The condensers **811** and **811′** of the fourth stage are referenced with respect to the corresponding condensers **88** and **88′** of the first stage so that they only need to withstand a maximum voltage of 30 kV. Similarly, the condensers **812** and **812′** of the fifth stage are referenced with respect to the corresponding condensers **89** and **89′** of the second stage and the condensers **813** and **813′** of the third stage. It can be seen generally that in this type of connection the condensers of order higher than the third stage are referenced with respect to the corresponding condensers of the stage having an order three times before.

FIG. 3*b* shows diagrammatically a form of construction of the cascade according to FIG. 3*a*. The two parallel plates employed, **814** and **815,** have a standard thickness of 1.6 mm. Each of the diodes **816 – 827** is placed between the two plates **814** and **815** in such manner that the electric field along each diode is substantially constant.

FIGS. 4*a* and 4*b* represent another form of hybrid cascade intended to be incorporated in an electrostatic projection gun. According to this latter model of hybrid cascade, as can be seen from the electrical diagram of FIG. 4*a*, the condensers of the first three stages are referenced with respect to the two input terminals of the cascade and the condensers of the last three stages are referenced with respect to the corresponding condens-

ers of the third stage. This type of hybrid cascade permits a more convenient application, the connections being simpler to effect.

Cascades of the hybrid type utilize, for some of their condensers, capacitances having a value greater than those employed in cascades of the parallel type. If the hybrid cascade shown in FIGS. 4*a* and 4*b* is considered with respect to the parallel cascade of FIGS. 1 and 2, for example, there is a difference in the value of the two capacitances which equip the third stage of the cascade. In the case of the hybrid cascade these capacitances are four times higher than that of the capacitances of the other stages, and the latter capacitances have approximately the same value, for the same performance characteristics, as those in parallel cascade.

The increase in value of the capacitances in the hybrid cascade does not however lead to a substantial increase in the dimensions of the cascade as compared with the parallel cascade, since, as the thickness of the dielectric is smaller, the dimensions of the plates of the various condensers are also smaller for the same capacitance value.

For the hybrid cascade, there is obtained a reduction of energy accumulated by the cascade and liberated in the event of a spark. This liberated energy is about 40% of the corresponding energy of the parallel cascade. The hybrid cascade is thus more favorable from the point of view of safety in the supply of high-tension to electrostatic projection apparatus.

The electrostatic painting gun of FIG. 5 includes a metallic charge electrode **830**. The electrode **830** is connected by a very short metallic conductor **831** to the output terminal **86** of a cascade voltage multiplier **832** of the hybrid type. This multiplier is in the form of a removable cartridge mounted in the barrel of the gun and is of the form illustrated in FIGS. 3*a* and 3*b*.

The transformer 84 of FIG. 3*a* is also placed in the body of the gun and is coupled to the cascade **832** by a connection **833**. The alternating voltage issuing from the DC-AC converter is led to the transformer **84** by the electric cable **83**, this cable being of small diameter as it only needs to carry a voltage of low value. A rear opening **834** within the gun enables the ready removal of the transformer and the cascade for repair or replacement.

FIG. 6 is illustrative of a generally conventional electrostatic powdering gun which has been modified in accordance with the invention. The gun is of the manual type and includes a charge electrode **835** connected by a short conductor to the output terminal **86** of the hybrid cascade multiplier **832**. The multiplier **832** in turn is coupled by the cable **833** to the transformer **84** supplied by the cable **83**. A removable rear portion **836** of the powdering gun contains the transformer **85** and permits the easy withdrawal of the transformer, the cable **833** and the cascade **832**.

The manual electrostatic flocking gun of FIG. 7 is provided with a charge grid **837** for the fibres to be projected. The grid **837** is joined by a short connection to the output of the hybrid cascade **832**, and the cascade in turn is coupled by the cable **833** to the transformer **84**. The transformer **84** is connected to the output of a conventional thyratron inverter (not shown) by the cable **83**. In a manner similar to that described above in connection with the powder gun of FIG. 6, a removable rear portion **838** which permits the extraction of the transformer **84**, the cable **833** and the cascade **832**.

The invention may be applied to all types of cascade voltage multipliers utilized in direct current high-tension generators, and also to all types of electro-static projectors having a cascade voltage multiplier built into the barrel. It finds an especially advantageous application for manual electrostatic projection guns for spraying coating products.

The terms and expressions which have been employed are terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding any equivalents of the features shown and described, or portions thereof, it being recognized that various modifications are possible within the scope of the invention claimed.

What is claimed is:

1. A cascade voltage multiplier device comprising, in combination:

a pair of electrically conductive surfaces in spaced apart relationship with each other;

a series of combination diodes interposed between the surfaces in electrically conductive relationship therewith, each of the combination diodes comprising a plurality of elementary diodes and being oriented to pass current in a direction substantially perpendicular to at least one of the surfaces; and

means for applying a voltage across the surfaces, each of the combination diodes being spaced from the surfaces by a distance sufficient to prevent undue breakdown of the elementary diodes and to subject the elementary diodes to substantially the same instantaneous reverse voltage.

2. A cascade voltage multiplier device as defined in claim **1**, in which the electrically conductive surfaces extend in flat substantially parallel planes.

3. A cascade voltage multiplier device comprising, in combination:

a pair of electrically conductive surfaces in spaced apart parallel relationship with each other;

a series of elongate combination diodes interposed between the surfaces in electrically conductive relationship therewith, each of the combination diodes comprising a plurality of elementary diodes and being physically oriented such that each combination diode extends in a direction substantially perpendicular to the surfaces, the elementary diodes and the surfaces being connected to provide a cascade multiplier of the parallel type; and

means for applying a voltage across the surfaces, each of the combination diodes being spaced from the surfaces by a distance sufficient to prevent undue breakdown of the elementary diodes and to subject the elementary diodes to substantially the same instantaneous reverse voltage.

4. A cascade voltage multiplier device comprising, in combination:

a pair of electrically conductive surfaces in spaced apart parallel relationship with each other;

a series of elongate combination diodes interposed between the surfaces in electrically conductive relationship therewith, each of the combination diodes comprising a plurality of elementary diodes and being physically oriented such that each combination diode extends in a direction substantially perpendicular to the surfaces, the elementary diodes and the surfaces being connected to provide a cascade multiplier of the parallel-series type; and

means for applying a voltage across the surfaces, each of the combination diodes being spaced from the surfaces by a distance sufficient to prevent undue breakdown of the elementary diodes and to subject the elementary diodes to substantially the same instantaneous reverse voltage.

5. A cascade voltage multiplier device as defined in claim **4**, in which each of the combination diodes is substantially perpendicular to the electrically conductive surfaces but is oriented at a slight angle with respect thereto.

6. A cascade voltage multiplier device for the barrel of an electrostatic coating projector, the device comprising, in combination:

a pair of electrically conductive surfaces in spaced apart relationship with each other;

a series of combination diodes interposed between the surfaces in electrically conductive relationship therewith, each of the combination diodes comprising a plurality of elementary diodes and being oriented to pass current in a direction substantially perpendicular to the surfaces;

means for applying a voltage across the surfaces, each of the combination diodes being spaced from the surfaces by a distance sufficient to prevent undue breakdown of the elementary diodes and to subject the elementary diodes to substantially the same instantaneous reverse voltage; and

mounting means for supporting the surfaces and the combination diodes on the barrel of the electrostatic projector.

7. A cascade voltage multiplier device for the barrel of an electrostatic coating projector, the device comprising, in combination:

a pair of electrically conductive surfaces in spaced apart parallel relationship with each other,

a series of elongate combination diodes interposed between the surfaces in electrically conductive relationship therewith, each of the combination diodes comprising a plurality of elementary diodes and being physically oriented such that each combination diode extends in a direction substantially perpendicular to the surfaces, the elementary diodes and the surfaces being connected to provide a cascade multiplier of the parallel-series type;

means for applying a voltage across the surfaces, each of the combination diodes being spaced from the surfaces by a distance sufficient to prevent undue breakdown of the elementary diodes and to subject the elementary diodes to substantially the same instantaneous reverse voltage; and

mounting means for supporting the cascade multiplier on the barrel of the electrostatic projector.

8. A device as defined in claim **7**, in which the cascade multiplier is removably supported within the barrel of the electrostatic projector.

9. In an electrostatic coating projection gun having a barrel portion, in combination:

a pair of spaced electrically conductive surfaces;

a series of combination diodes interposed between the surfaces in electrically conductive relationship therewith, each of the combination diodes comprising a plurality of elementary diodes and being oriented to pass current in a direction substantially perpendicular to the surfaces, the elementary diodes and the surfaces being connected to provide a cascade multiplier of the parallel-series type;

high-tension generator means for applying a voltage across the surfaces, each of the combination diodes being spaced from the surfaces by a distance sufficient to prevent undue breakdown of the elementary diodes and to subject the elementary diodes to substantially the same instantaneous reverse voltage; and

mounting means for supporting the cascade multiplier on the barrel portion of the gun.

10. In an electrostatic projection gun as defined in claim **9**, the gun comprising a manual electrostatic projector.

* * * * *

"MY TRX"
All band CW transceiver 5 watt QRP plus general coverage reception.

(2001)

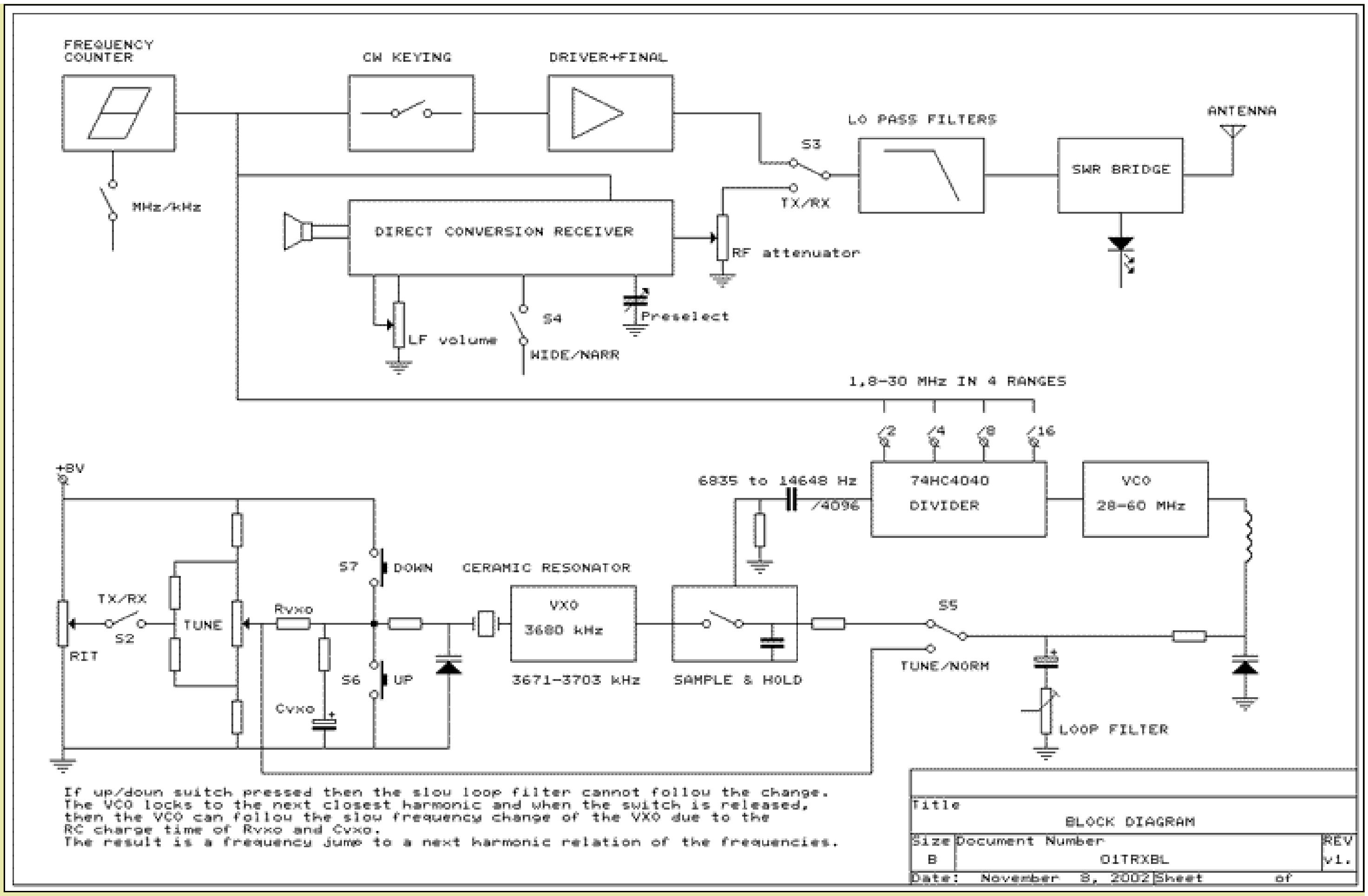
KLIK HIER VOOR DE NEDERLANDSE VERSIE

Ready for QRP work

Contact with the world
"MY TRX" is indeed my transceiver. It is not a perfect transceiver, but good enough for a lot of perfect QSO's. The transceiver has general coverage reception from 1.8 to 30 MHz. It can transmit on all amateur frequencies if there is a suitable low pass filter for the transmitter installed.
It is a simple QRP transceiver with acceptable performance but it has full frequency coverage and is constructed with easily available parts. You can also use it as a simple, stable RF generator or frequency counter! That is more than a lot of other beautiful transceivers offer!

The design
In principle it is a VFO from 28 to 60 MHz with a special frequency stabilizer and a frequency divider (/2; /4; /8; /16) to generate the working frequency. This signal is amplified to 5 watt and is also used for the Direct Conversion receiver.

Block diagram



Block diagram.
big diagram

The VFO is special

Working principle
(See the block diagram)
A VCO with a frequency range from 28 to 60 MHz is followed by a frequency divider to obtain the working frequency. The division ratio is /16; /8; /4/; /2 for the ranges 1.8-3.5 MHz; 3.5-7.0 MHz; 7.0-14.0 MHz and 14.0-30.0 MHz
Harmonics of the VCO frequency divided by 4096 are locked to a VXO. If locking occurs, there is a small frequency range of approx. 15 to 262 kHz (depending on the frequency band, 15 kHz for 160 m, 262 kHz for 10 m), tuneable by the 10 turn potmeter of the VXO.
By pressing the up/down switches, it is possible to go to the nearest next small frequency range that is tuneable by the VXO.
For large frequency changes, there is a switch so that you can tune the VCO close to the desired frequency with the 10 turn potentiometer.

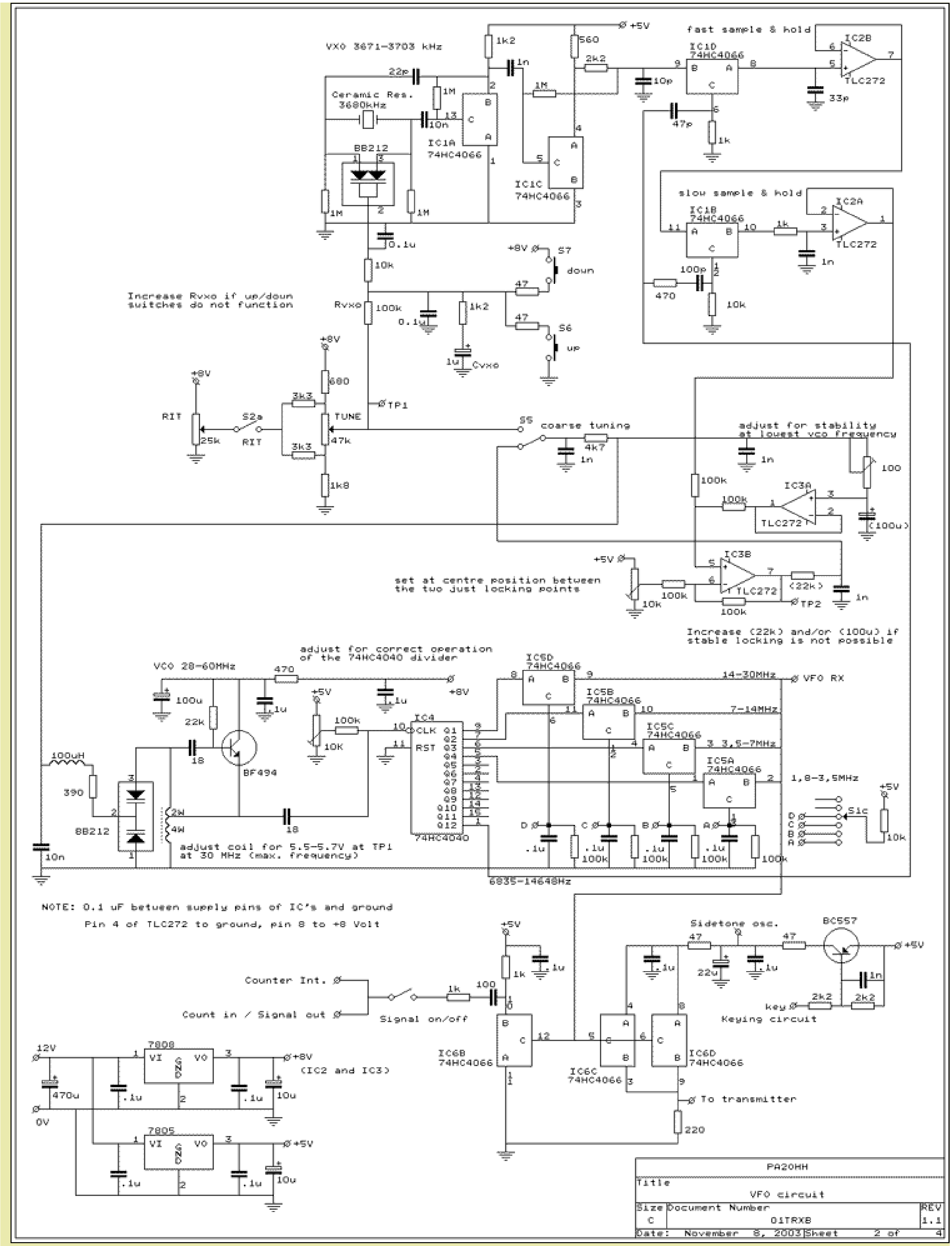
Frequency locking principle
The VCO frequency is divided by 4096, giving a frequency range from 6835 to 14648 Hz.
This frequency is used to control the sample & hold circuit. The input of that circuit is the VXO.
The output of the sample & hold controls the VCO. A frequency lock will occur if:
N x (6835 to 14648 Hz) = VXO frequency(3671 to 3703 kHz)
That means that for each integer value for N between 250 and 541 there is a frequency lock.
When there is a lock, the frequency variation of the VCO is:
4096/N x (3671 to 3703 kHz) with N between 250 and 541.
At low frequencies, the frequency variation is less than at high frequencies. At 1.8 MHz the frequency variation is half of that at 3.6 MHz, at 3.68 MHz it is exactly the same as the variation of the VXO and at 7.36 MHz it is twice the VXO variation.

Frequency change
There are two methods implemented to change to other harmonic locks (other values of N between 252 and 541):

1. For big frequency changes, set S5 to "tune", and the VCO is controlled by the 10 turn tuning potentiometer. Tuning close to the desired frequency (read out via frequency counter) is possible by rotating the 10 turn tuning potentiometer.
   Set S5 to normal and the VCO will lock to the closest integer value of N (between 250 and 541).
2. For small frequency steps within one band, press the "up" key S6 or "down" key S7.
   This will cause a sudden frequency change of the VXO. The loop filter cannot follow this sudden change and will lock to the closest harmonic relation (closest N factor). After releasing the switch, the VXO will slowly (due to Rvxo and Cvxo) go back to the original frequency and the VCO will follow that with a new N factor, + or -1 to 3 from the old N. Important is that the frequency jump of the VXO is sufficient. This only happens if the tuning potentiometer is below mid-range when pressing the "down" switch S7 or above mid-range when pressing the "up" switch S6.

So method 1 is for large frequency changes (large changes of N) to go to another band and method 2 is for small frequency changes (small changes of N), within one amateur band.

VFO diagram



Circuit diagram of the VFO, modified circuit in October 2002 for better reproducibility.

Circuit diagram of the VFO, modified circuit in October 2002 for better reproducibility.

big diagram

The VXO with ceramic resonator

The ceramic resonator is critical. I found some very bad samples and some very good ones. The bad one's were even less stable than a RC oscillator! So try to find a good one. The frequency is not critical and can be any value. The reason for a ceramic resonator instead of a crystal is that with a ceramic resonator, the VXO frequency deviation is bigger and the VXO has a better linearity. The frequency variation has to be considerably more than 60 MHz / 4096 = 14648 Hz, otherwise the up/down switches will not work.
Stability is just acceptable.

The RIT

The RIT is not linear. The RIT frequency depends on the VXO frequency. Tune to zero beat with the RIT at centre position (or S2 off) when receiving, then turn the RIT potentiometer to the left or right to obtain the desired audio frequency of the received CW signal.
For the higher bands the frequency variation of the RIT control is bigger. The resistors around the RIT potentiometer are selected for less RIT frequency variation near the centre position of the RIT potentiometer.
The RIT switch S2 is toggled together with the TX/RX switch S3.

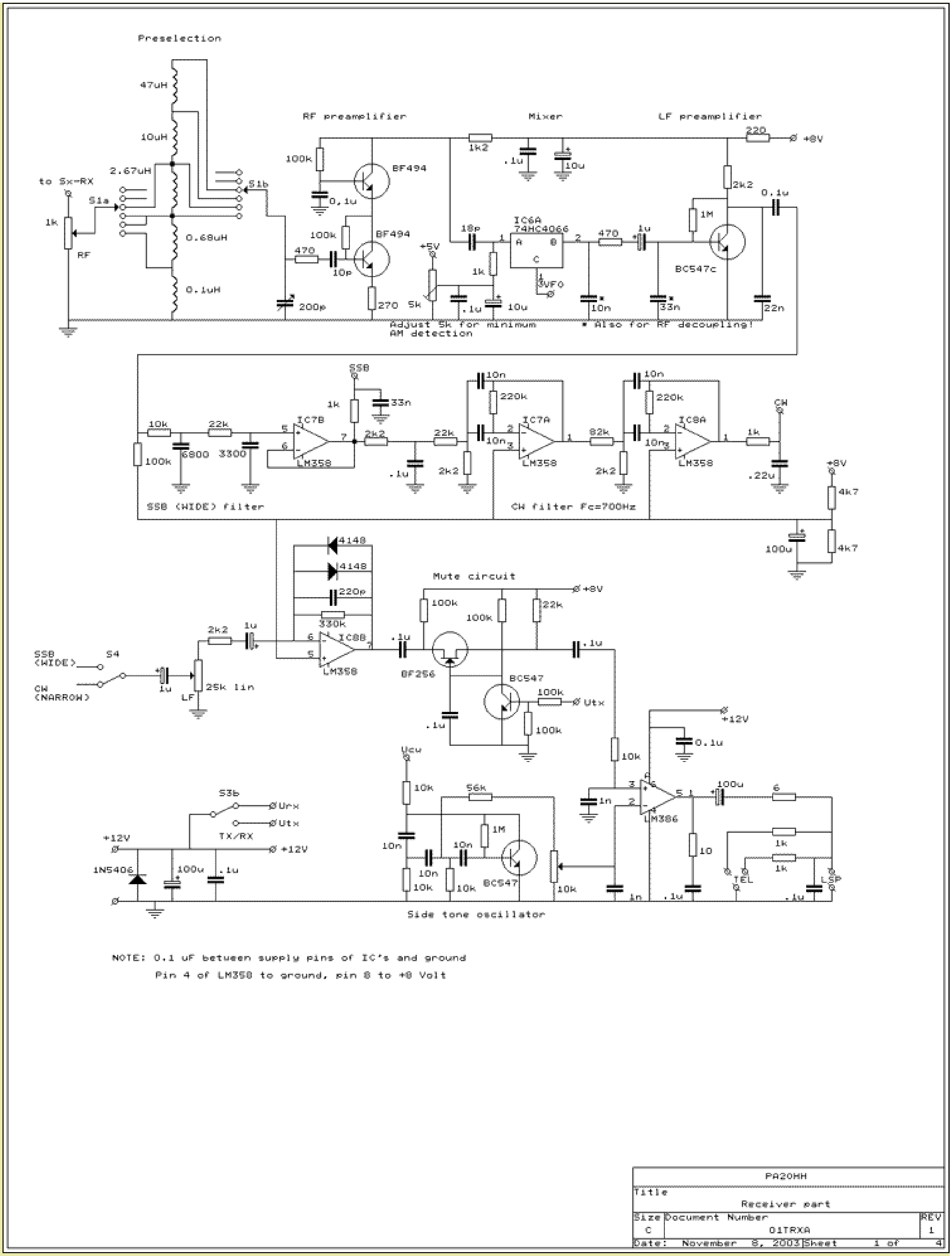
The Sample & Hold circuit

There are two sample & hold circuits. One with a small capacitor for fast sampling and a second one with a bigger capacitor for slow sampling of the output of the first sample & hold. This second one does not discharge between two sampling moments, due to the bigger capacitor.

The Control Loop

Two potentiometers are used to control the stability. The 100 ohm potentiometer in series with the 100 uF capacitor is adjusted for stability at the lowest VCO frequency (VCO at 28 MHz). The 10k ohm potentiometer is set to the centre between the two "just locking" positions. If it is not possible to get the VCO locked, increase the 100 uF capacitor and/or the 22k resistor of the loop filter. If the up/down switches do not work correctly, increase Rvxo. All cables from the control loop circuit to the switches and tuning potentiometers are screened.
Adjustment of the loop potentiometer can be done with an oscilloscope at TP2. A very simple and perhaps even better method is to tune to a strong carrier just above 14 MHz and adjust the 100 ohm potentiometer so that you will hear the cleanest distortion free audio tone.

Direct Conversion Receiver diagram



Circuit diagram of the direct conversion receiver

Circuit diagram of the direct conversion receiver

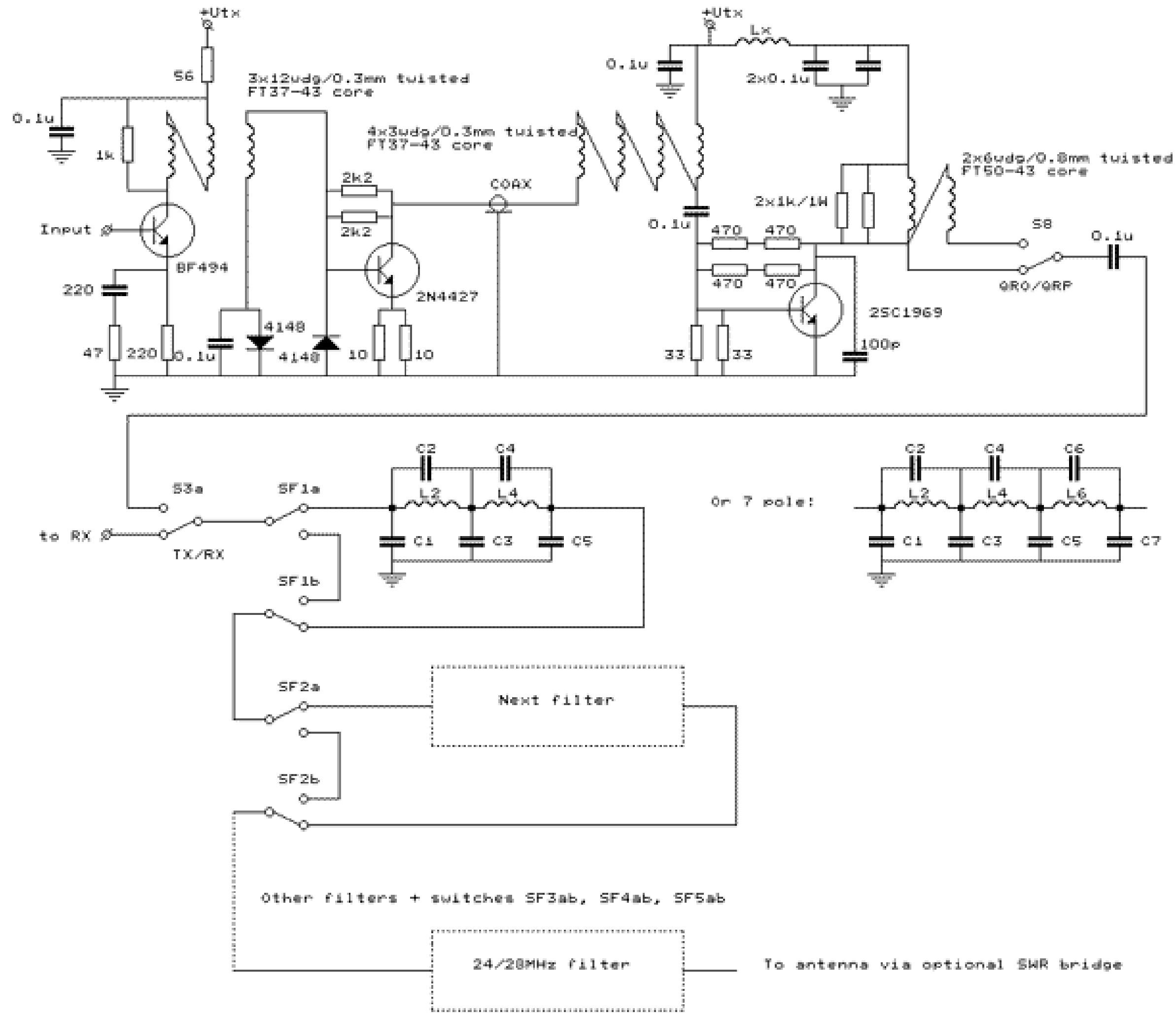
big diagram

The Direct Conversion receiver

At the input is an RF preselector (inductances soldered direct on switch S1a/b), an RF preamplifier and a 74HC4066 is used as mixer. The audio preamplifier is followed by an audio filter for SSB reception and a CW filter. Finally the LM386 feeds the loudspeaker or headphones.
The LF volume control is a little unusual, but in this way the LF amplifier gain and also the noise of that amplifier decreases at lower volume settings. The first design had some irritating noise left at low volume settings.
The RF preamplifier is very important. Without it there is a lot of 50 Hz / 100 Hz hum when you use a power supply connected to the mains due to Local Oscillator leakage from the mixer to the antenna. This depends on the antenna, frequency band and power supply you are using. A lot of Direct Conversion receivers have this problem. The RF preamplifier does suppress this LO leakage and increases the sensitivity at the higher bands.
Not all preamplifiers do suppress the Local Oscillator leakage from the mixer to the antenna. The first version without the second transistor in the collector did not suppress the LO leakage and also an emitter follower was not usable.

If you want to read details about mixer and RF amplifier, go via the home page index to the 4 band VXO tuned QRP transceiver.

Transmitter diagram



Frequency	C1	C2	C3	C4	C5	C6	C7	L2	L4	L6		F2	F4	F6
1.8	1132	114	2300	324	956	none	none	4.90	4.20	none	Calculated			
(2)	1000	100	2220	370	1000						Used value	6.7	4.3	none
	T80-2 core: L2=30w/0.8mm L4=28w/0.8mm													
3.5	566	57	1150	162	478	none	none	2.45	2.10	none	Calculated			
(4)	470	51	1160	192	470						Used value	13.4	8.6	none
	T80-2 core: L2=21w/1mm L4=20w/1mm													
5.0/7.0	203	49	528	233	476	184	185	1.26	0.97	0.90	Calculated			
(8)	200	47	490	200	440	200	200				Used value	20.4	10.6	12.4
	T50-2 core: L2=16w/1mm L4=14w/1mm L6=13w/1mm													
10/14	141	24	264	117	238	92	93	.624	.483	.448	Calculated			
(16)	36	18	236	100	236	96	100				Used value	40.8	21.2	24.8
	T50-2 core: L2=11w/1mm L4=10w/1mm L6=9.5w/1mm													
18/21	94	16	176	78	158	61	62	.416	.322	.299	Calculated			
(24)	94	13	172	56	150	11	56				Used value	61.2	31.8	37.2
	T50-6 core: L2=10w/1mm L4=9w/1mm L6=8w/1mm													
24/28	46	9	117	41	110	36	26	.290	.250	.190	Calculated			
(32.1)	44	11	118	31	111	36	27				Used value	101.1	49.9	59.5
	T50-6 core: L2=8w/1mm L4=8w/1mm L6=7w/1mm													

Filters from tables 22.12 and 22.13 RSGB Radio Communication Handbook 6th edition

Note: L in uH, C in pf
Note: 7MHz filter also usable for eventual new 5MHz band
Note: Adjust C2, C4, C6 for correct F2, F4, F6 with dipmeter
Note: All filters 50 dB attenuation

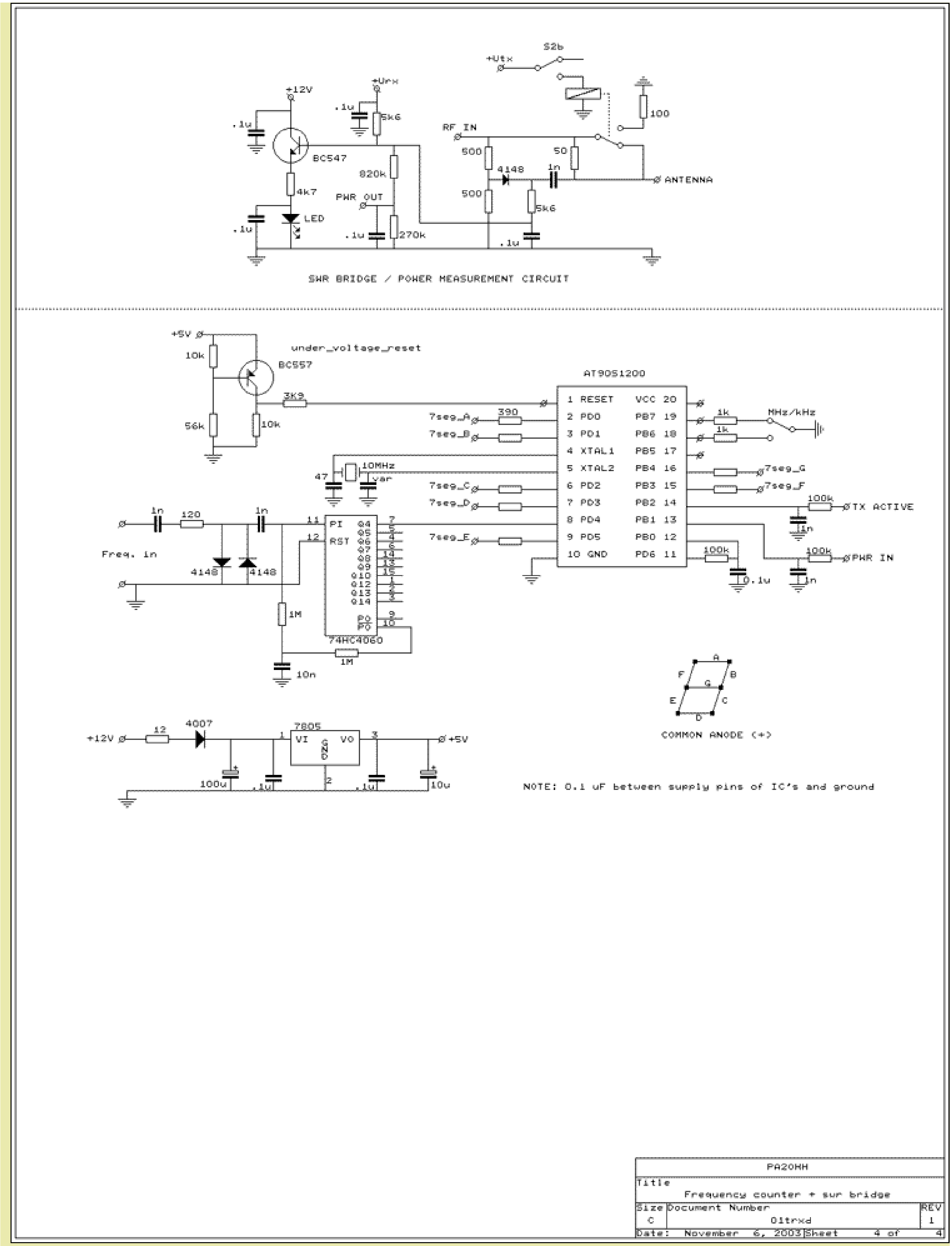
PA2OHH		
Title: Transmitter part of MY-TRX		
Size: C	Document Number: 01TRXC	REV: 1
Date: November 6, 2003	Sheet 3 of 4	

Circuit diagram of the transmitter

Circuit diagram of the transmitter
big diagram

The Transmitter
The VFO signal is amplified with two parallel sections of a 74HC4066 and is switched on and off if key down and up by the BC557. This RF signal goes to the driver with transistor 2N4427 and final amplifier with a transistor 2SC1969. The elliptic filters for 1.8; 3.5; 7.0; 10/14; 18/21 and 24/28 MHz do suppress the harmonics. The 24/28 MHz filter is always in use. The filters are also used during reception to suppress strong 7.1 - 7.3 MHz broadcast stations when listening at 3.55 to 3.65 MHz. When a filter is switched on, all the filters for the higher frequencies are also switched on to suppress the spurious emission accross the switches. Example: When transmitting on 7 MHz, the 10/14 and 18/21 filters are also switched on.
The design of the elliptic filters is based upon tables from the RSGB Radio Communication Handbook, sixth edition, table 22.12 and 22.13.

Frequency counter and swr bridge diagram



Circuit diagram of the optional frequency counter and swr bridge

Circuit diagram of the optional frequency counter and swr bridge
big diagram

The Frequency counter and SWR bridge
(Any other frequency counter can be used and the SWR bridge is optional)

The frequency counter with one 7 segment LED display

For an explanation about the working principle, go via the home page index to the simple frequency counters. This version also displays the RF power if key down during TX or the supply voltage if key down during RX.
The SWR is also indicated via a LED. Of course you can use any other frequency counter and SWR meter.

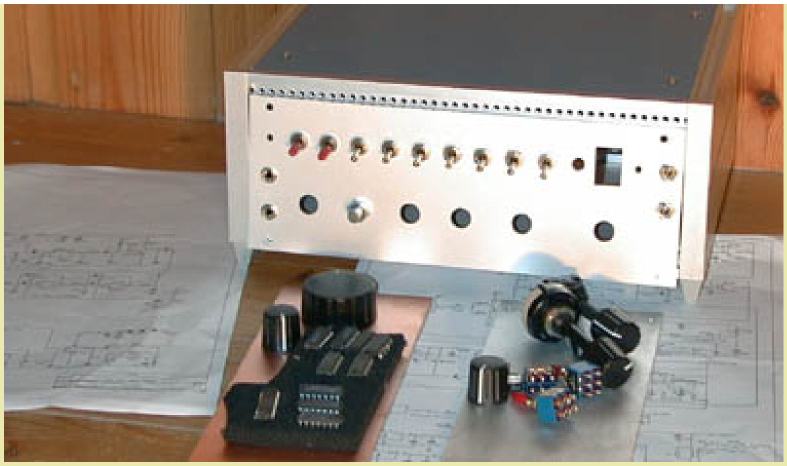
Notes
The VXO and VCO are placed together in a screened enclosure. The frequency counter is also screened.
Built via the ugly method (dead bug method). Parts are soldered at both sides of he double sided unetched print.
Inductances are commercially available types looking like big resistors.
Do not use a HCT type but a HC type!

Performance
Sensitivity: 0.15 to 0.3 uV signals are readable
AM dynamic range: 85 to 100 dB (good)
RX current: 90 mA
Transmit power (12 Vdc):
- QRO: 7 to 9 W for the bands 1.8 to 24 MHz, 4.5 W at 28 MHz.
- QRP: 2.5 to 3 W for the bands 1.8 to 24 MHz, 2 W at 28 MHz.
Suppression of spurious emission: below 30 MHz: 43 dB, above 30 MHz: 55 dB

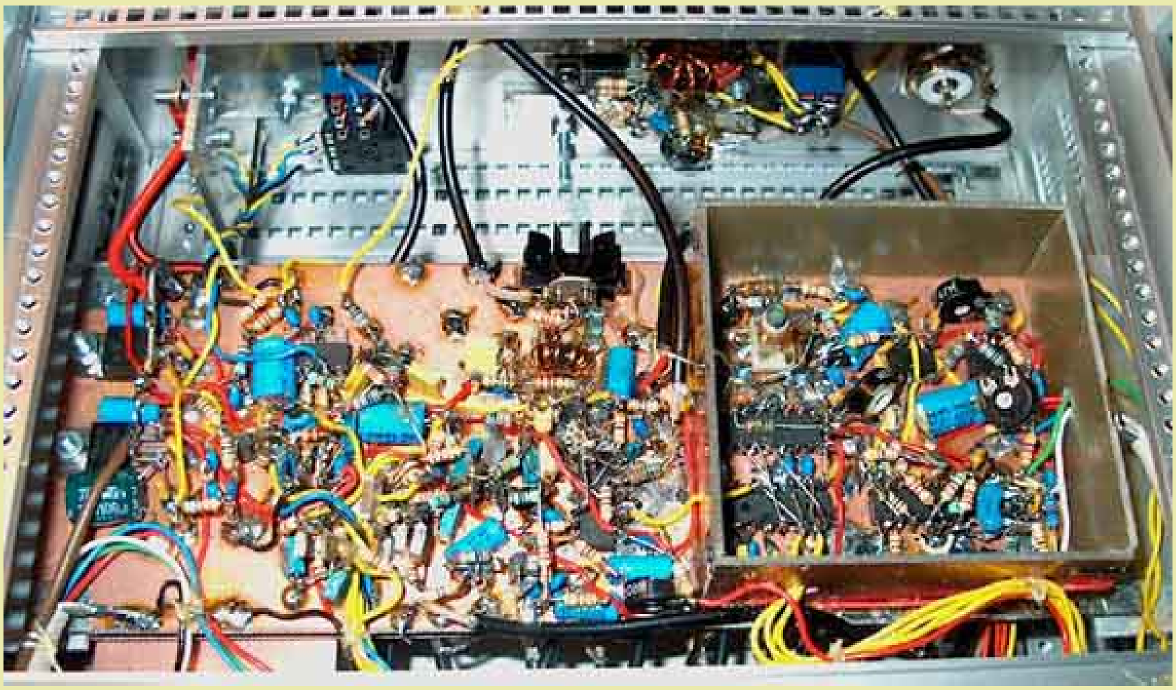
SOFTWARE FOR THE FREQUENCY COUNTER

"FREQTRX1.ZIP" WITH "FREQTRX1.ASM" TO PROGRAM THE FREQUENCY COUNTER

PHOTOGRAPHS

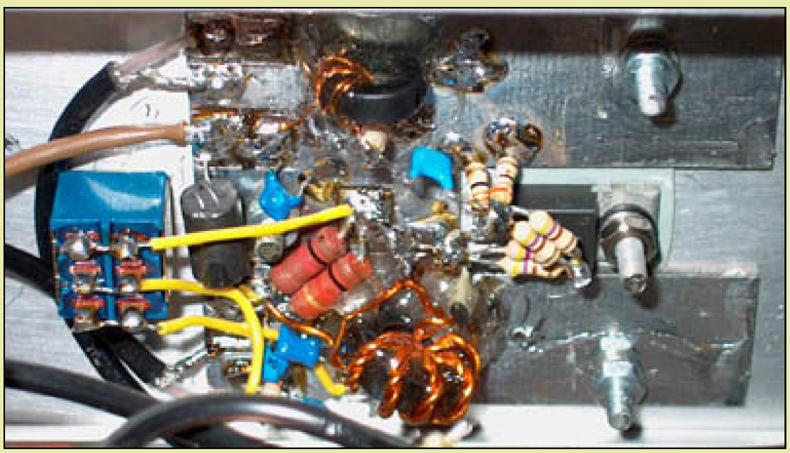


The Birth of the "MY TRX" Transceiver.



The VFO, Direct Conversion RX and PA driver

The SWR bridge, Lo-pass filters and Frequency counter



The Final amplifier with 2SC1969 transistor and QRO - QRP switch
(at the back side of the transceiver)

Back side of the transceiver

BACK TO INDEX PA2OHH

SIMPLE RF - LF INTERFACE
FOR A SHORTWAVE RECEIVER

(2009)

KLIK HIER VOOR DE NEDERLANDSE VERSIE

The shortwave receiver GRUNDIG Yacht Boy 80 with the RF - LF interface.

Why a RF - LF interface?
Nowadays it is possible to buy a nice portable shortwave receiver for a very reasonable price with which you also can receive SSB. Incredibly, the long wave, medium wave, short wave and also the FM band, even in stereo! And that for an amount of money of which you could only dream of in the past!
I bought the GRUNDIG Yacht Boy 80. No top receiver of course, but excellent to use as a portable receiver. The frequency can be adjusted in increments of 1 kHz and there is an extra button on the side panel for fine tuning of SSB signals. A great receiver for many pleasant hours of listening at various locations. Similar receivers are for example the Sangean PT-80 and the ANJAN DTS-09.
But I also wanted to connect an external antenna and to connect the LF output to the soundcard input of my computer. The receiver has a connector for an external antenna. But with an external antenna, the receiver was quickly overloaded. And the Local / DX switch which does attenuate the antenna signal, had too much attenuation. Therefore, a very simple RF - LF interface was made with an adjustable potentiometer as RF attenuator and a matching network with resistors to connect the LF output of the receiver with the soundcard input of the PC. Digital modes can be decoded now with the PC.

The very simple RF - LF interface with an adjustable potentiometer as RF attenuator and a matching network to connect the LF output to the PC.

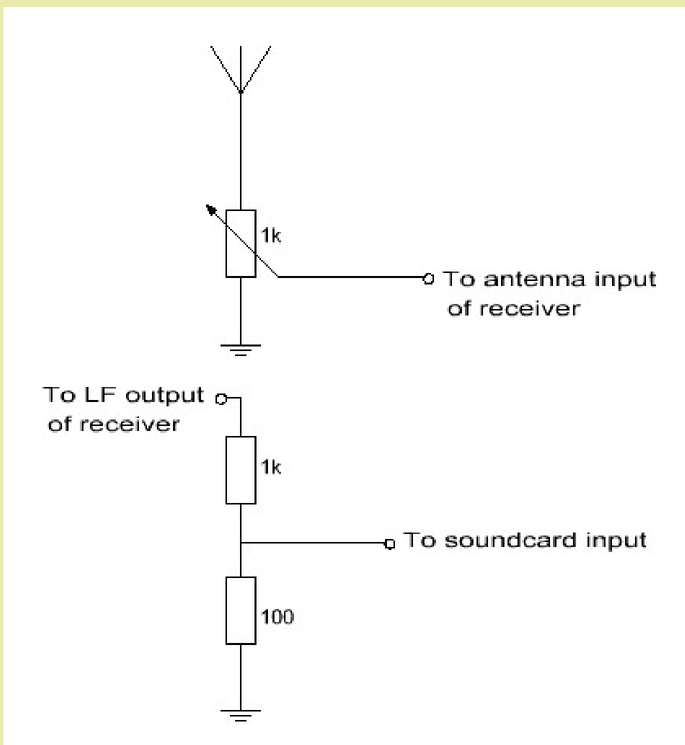
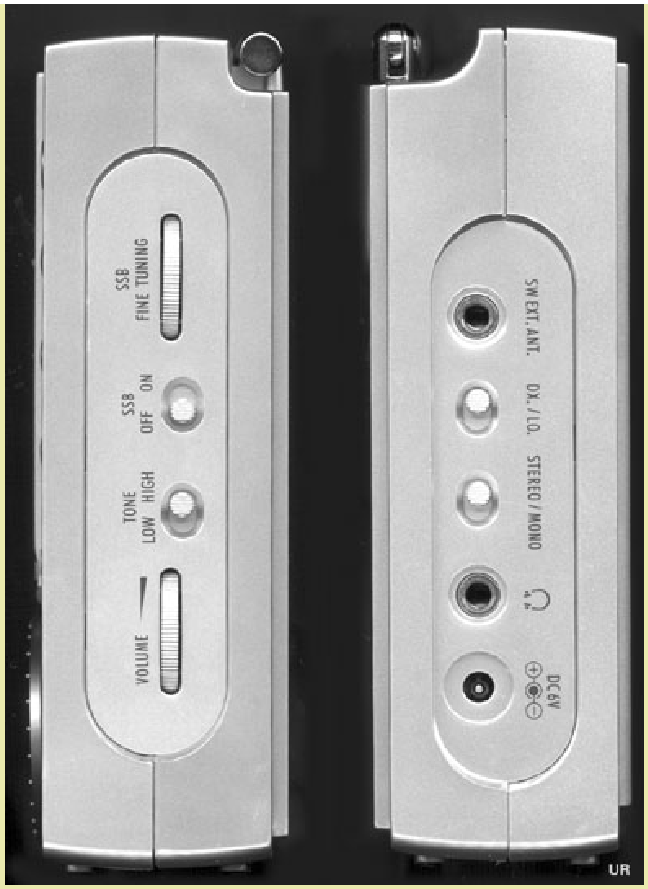
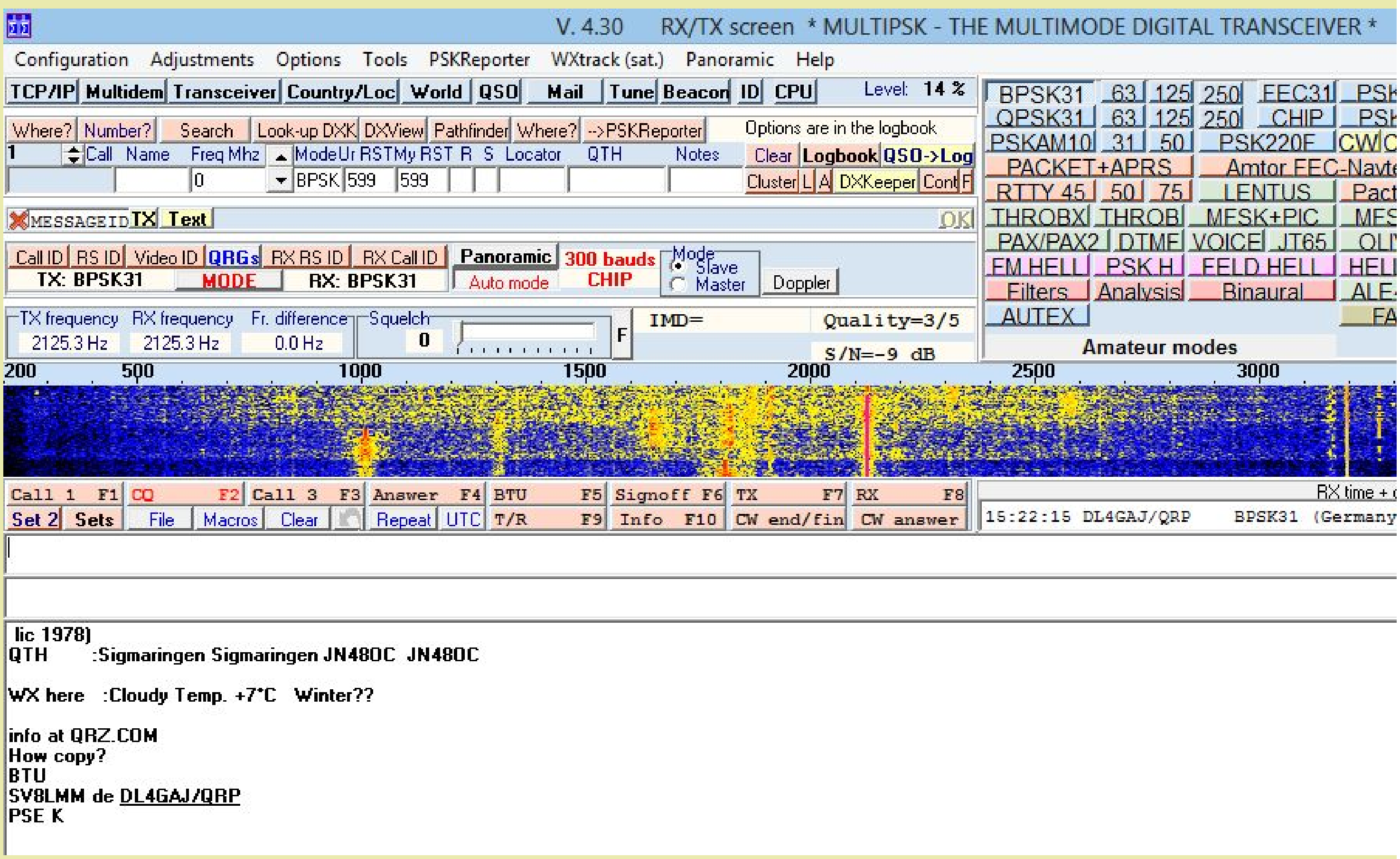


Diagram.



Knobs and connections at the side panels.



PSK31 reception is possible now with the PC.
Here with the program Multipsk van F6CTE.

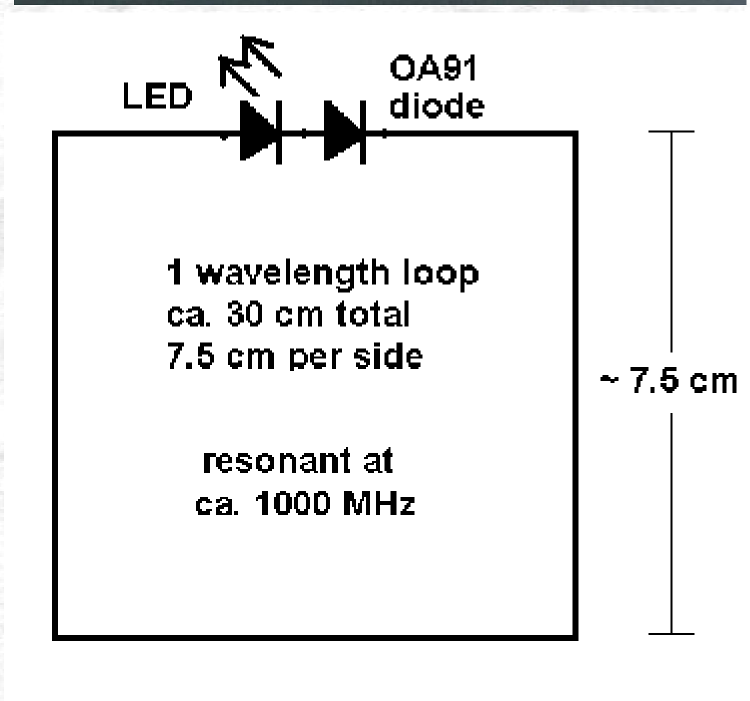
The Sangean PT-80 looks identical to the GRUNDIG Yacht Boy 80.

BACK TO INDEX PA2OHH

Simple demonstration to show mobile phones emit radio waves

Dr Jonathan Hare, Sussex University, Department of Physics, Falmer, Brighton. BN1 9QH
Note: this article is in press: Elektor Magazine, July-August 2010, p. 56-57

For other experiments with this device please see my full article at: mobile phone detector



left: mobile phone radio wave detector and right: the simple schematic. Below: detail of the LED and germanium diode.

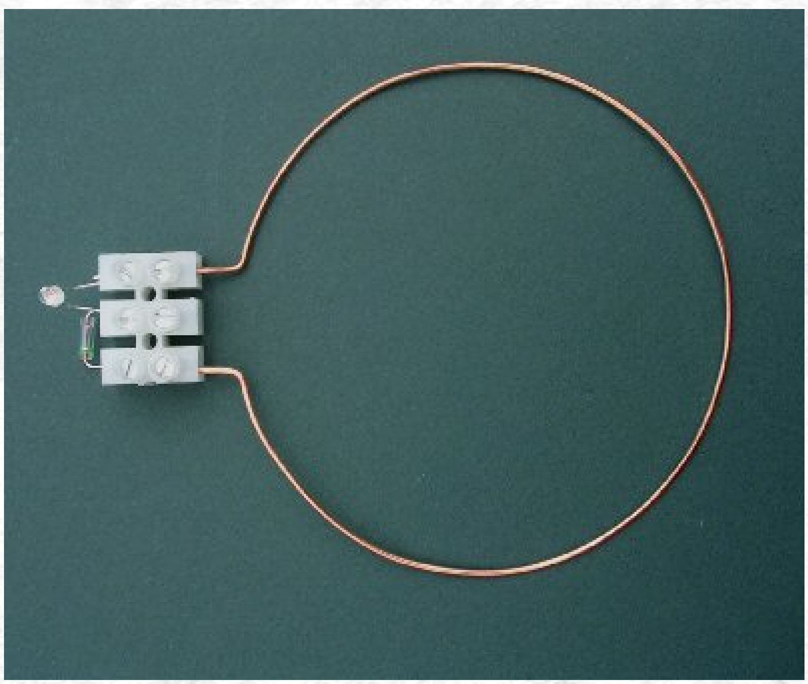
IMPORTANT NOTE: this device works very well on the old style mobile phones (as shown in the photo above). However, it does not always work well with modern smart phones. This may be because modern phones use higher frequencies, less power and use the power in a slightly different way (e.g. spread

spectrum). Some smart phones do work and success may be due to the signal strength of the local mobile phone mast nearby. If you are in a low signal area the phone will create more power to ensure reliable communications. If you are in a very strong signal area (very near the local network) your phone will drop its output power and consiquently there will be less power to pick-up and to convert to a voltage to light the LED.

This is a very simple and cheap device that demonstrates mobile phones ('cell phones' or 'handies') generate radio waves. We have a 30 cm (7.5 cm per side) full-wavelength loop antenna (a 'Quad' to radio amateurs) connected to a germanium diode and a hyper-bright LED. The loop can be made of copper wire, thin sheet metal or a track on a pcb. The diodes need to be wired correctly. I think the germanium diode is needed as the LED probably has too great a self-capacitance to perform at the very high AC frequencies generated by the phone (ca. 900 or 1800 Hz) but will work well with the DC pulses from the germanium diode (which has a very small capacitance).

To show the mobile generates radio waves put the mobile near to the loop and dial a number (use a free phone number, e.g. your voice mail) or text. The radio waves will induce a voltage into the loop, large enough to light the LED. The LED will flash indicating the digital data being sent by the mobile phone transmitter. You may need to set your phone to 'GSM 900/1800' rather than the '3G' network in the settings menu.

parts:
germanium diode: Maplin Electronics: QH71N or Rapid Electronics: 47-3114
LED: Maplin Electronics: UF72P or Rapid Electronics: 55-0085



A very simple connector block version and a circular 1 wavelength loop

THE CREATIVE SCIENCE CENTRE

Dr Jonathan Hare, Brighton, East Sussex. BN1 9QJ.

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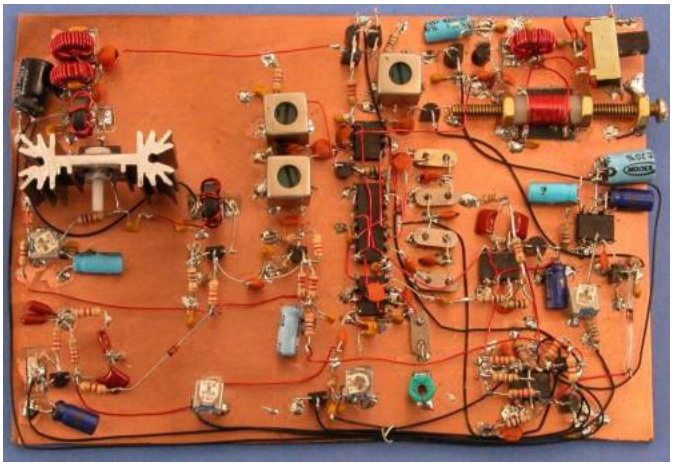
Building the KD1JV MMR-40 "dead bug" style



Introduction:

What is the MMR-40? It is a 40 meter rig with SSB (voice) and CW (Morse code) operating modes. This is a low power (QRP) rig with up to 6 watts CW or PEP (peak envelope power) output. This rig was designed for the ARRL Homebrew Challenge, the goal of which was to come up with a functional CW/SSB rig design which could be reproduced for under $50.00 using common hand tools and a minimum of test equipment. The MMR-40 was one of two winners for this contest. In theory, the parts cost of all new parts in single piece quantity is about $32.00. The actual out of pocket costs will be some what higher, because of the shipping and handling costs to get the parts to you. The cost of wire and any tools you may need to buy are also not included in the base price. The full parts list with distributors part number is located at the end of this page.

The MMR-40 is also available as a compete kit with double sided circuit board and cabinet for a professionally looking rig. The kit is available from Hendricks kits www.qrpkits.com


Kit version of MMR-40 board

This document will attempt to provide the basic knowledge needed to build the MMR-40 dead bug style from the schematic and is geared for the novice builder. However, painfully detailed step by step instructions are not supplied. To do so would make this a much longer document than it already is and would drive me nuts writing. Helpful hints are frequently given for things that are not all that obvious. It is assumed that you are intelligent so can figure out some details on your own, have reasonable mechanical skills and dexterity. You must often work with both hands, holding a part in one hand and the soldering iron in the other. Sometimes it helps to be able to handle three things at a time!

If you have never built a piece of electronic equipment before and have little or no knowledge of electronics in general, there are a number of things you need to learn before you begin. First, you need to be able to read a schematic and relate the schematic part symbols to the actual physical part. Once this is understood, assembly is simply an exercise in mechanics. It is not all that important that you understand the function of each part or how the circuit works as a whole . What is important is that it is wired correctly. Understanding how the circuit works is important if you need to figure out why it doesn't.

It is suggested that additional resources like the Internet, the ARRL handbook and similar publications be consulted for a more in depth discussion of schematic symbols, what the parts actually do, basic circuit theory and building methods.

Possible construction methods:

There are three construction methods you can choose from to build this rig. The best method is to make a printed circuit board. The second best is to make a pesudo circuit board, and finally to use the classic "dead bug" on ground plane method. Each method has its advantages and disadvantages.

Printed circuit version:

For those of you who know how to make a printed circuit board, this is perfered to building the rig dead bug style. You will end up with a better looking and most likely more reliabe rig this way. Single sided board artwork can be down loaded as a pdf file. The layout is shown as "through board view". This view allows printing directly to toner transfer film and the proper image reversal is done when you transfer the image to the board. This view is also consistant with photo sensitive boards, as you want the printed side to be against the circuit board.

You may have to check your printer preferences to make sure it prints to scale. X and Y reference distances are on the drawing so you can check to see that the scale is correct. A second pdf file shows the part locations, jumper locations and part values. Even though the layout is for a single sided board, using a double sided board is a good idea. The top side will have to be masked so it doesn't etch (I cover it with vinal electrical tape) and then all the holes countersunk for parts which do not connect to the bottom ground. The ends of all the parts which connect to ground are soldered to both the bottom and

top side of the board. Using a double sided board will allow mounting the PTO coil on the top side of the board. Note that some of the point to point jumpers required are best made on the bottom of the board. Down load board layout file Down load parts placement layout file

Pesudo circuit board method:

This method involes drilling all the holes for the parts in the circuit board matterial but with out etching the board. Instead, all the connections are hand wired. To use this method, you will need a drill press and a selection of carbide pcb drill bits. Carbide drill bits can be bought as surplus or resharpened bits from a number of sources at reasonable prices. Keep in mind these bits are very fragile and break easialy with any side torque, so a drill press is required if you expect to use them to make more than one hole. Do not be tempted to use cheep steel twist bits, as these will burn up and get dull after only a few holes have been drilled.

Print a mirror image of the board layout diagram. Tape this to bottom, copper side of the board and drill all the holes. Now you have to counter sink all the holes which do not connect to the ground plane. This is to remove the copper from around the holes so you can attach wires to the componet leads which need to be inter-connected and not short out to the copper ground plane. For counter sinking, you can use a 0.1" dia carbide router bit or a standard 1/8" drill bit, as you are not drilling all the way through the board.

Once all the holes have been drilled and countersunk, you can start installing parts and making the interconnections between them. Print a new copy of the board layout (also a mirror image) to use as a wiring guide, duplicating the connenctions normally made by the copper tracks.

Dead bug method:

This method is discribed in detail later in the document.

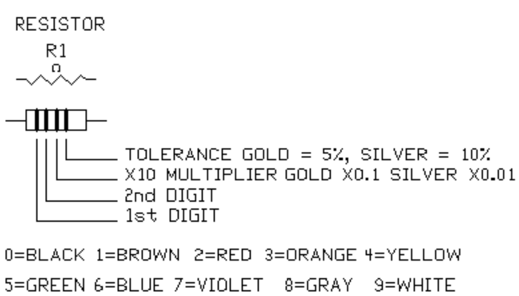
Reading schematic:

A schematic is a road map showing how a circuit is wired together. Parts are shown as a symbol and connections between the parts as lines. Some lines cross. If two or more lines cross and there is a dot at the junction, it means these lines are connected together. If there is no dot where lines cross, there is no connection between them. A good schematic is drawn so that there is some sense of signal flow. Typically, this is from left to right with inputs on the left and outputs on the right. A good physical placement of the parts will try to follow the same general layout as the schematic, as much as maybe possible.

With this basic understanding of how the circuit is represented, all we need to know now is what physical part each symbol represents. Any electronic circuit will use basic parts like resistors, capacitors, diodes and various active devices, such as transistors, FETs and ICs. The following will show the schematic representation of a part and how to determine its value.

Resistors:

Resistors are little "dog bones" with a wire coming out of each end. They are bi-directional so it doesn't matter which end is used to connect to some other point. The value of the resistor is marked by color bands. The first three bands indicate the numerical value and the fourth is the tolerance. 5% resistors, which are the most commonly used, have a gold band as the last color and is used as the marker to determine in which direction the other colors are read in. The first two colors are read as numbers and the third color indicates the number of zero's which follow. Therefore, a resistor with the colors Brown Black Black Gold is a 10 ohm 5% resistor. A resistor with the colors Red, Red, Red is 2200 ohms or 2.2 K. A resistor with a value of less than 10 ohms will have a gold or silver band as the third color. In this case, a gold band means the first two digits are multiplied by 0.1 and a silver band by 0.01. Therefore a 1 ohm resistor will be marked Brown, Black, Gold, Gold and a 0.01 ohm resistor would be Black, Brown, Silver, Gold.

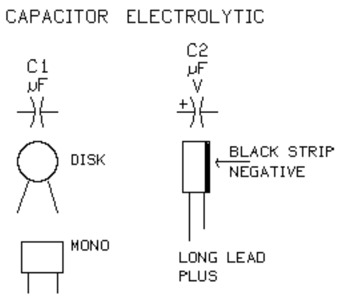


Capacitors:

Capacitors come in a variety of shapes, sizes and types. The types used in the MMR-40 are Ceramic Disks, which are round, flat disks and usually have a tan or brown color. Multi-layer ceramics or Monolithic (Mono) are squarish and usually yellow or occasionally blue. Mylar Film, which are often green or white in color and finally, Electrolytics which are round cans with a plastic wrapper. The first three types, disk, mono and film capacitors have no voltage polarity so it doesn't matter which lead goes to what part of a circuit. Electrolytics are voltage polarity sensitive and can actually explode if improperly installed. The long lead is always the positive lead and the negative lead is marked with a black or gray stripe along the body of the can.

Values of capacitors are always marked with two or three numbers. The first two digits are the integral value and the third digit is the number of zero's which follow. The value is in picofards (pfd). Sometimes there will be a letter following the numbers and this can either indicate the type of capacitor or its tolerance. The meaning of the letter varies between manufacturers, so no hard fast rules apply to this letter. NPO type ceramic disks usually have a black dot on the top edge of the disk.

Therefore a 22 pfd ceramic disk capacitor will be marked "22". A 220 pfd cap would have the numbers "221" marked on it. Some monolithic caps will have have a third digit, even if the value is less than 100. If the last digit is a 0, that means no zeros after the first two digits. A 0.01 ufd cap will be marked 103 and a 0.1 ufd cap 104 and so on.



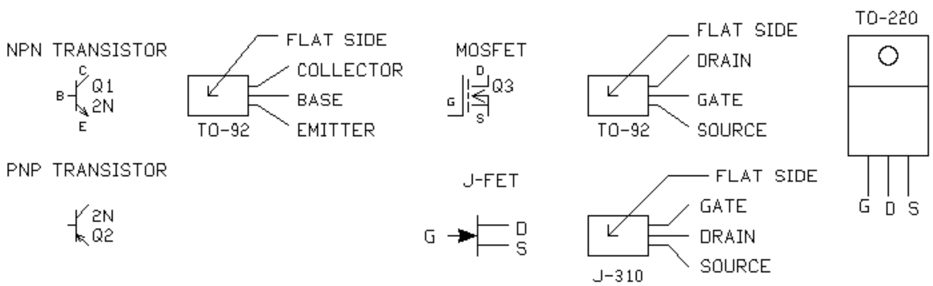
Semi-conductors:

Here is where things get interesting. There is a wide range of semi-conductors and the types of packages they come in. These parts must be wired in correctly or they will self destruct (more often than not). Semi-conductors may be transistors (NPN and PNP types), field effect transistors (J-FETs or MOSFETS), Diodes and Integrated Circuits (ICs).

Bi-polar Transistors:

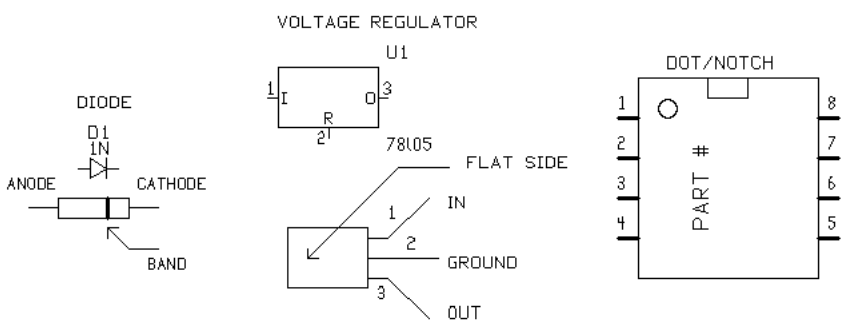
Bi-polar transistors come in two flavors, NPN and PNP. NPN types require a positive voltage on the base in respect to the emitter to function. PNP are the reverse, requiring a negative voltage on the base in respect to the emitter. J-FETs and MOSFETS also come in two flavors, N type and P type. Like the Bi-polar types, N types use a positive gate voltage to turn on and P types a negative voltage.

The pin outs for transistors and FETs shown below are for the types used in the MMR-40.



Intergrated Circuits (ICs)

IC pin outs follow a strict pin numbering scheme. Pin 1 is always in the upper left corner and the pins are numbered in a counter clock wise direction down the left side and up the right side. The Pin 1 end of the part is marked with either a dot or dimple next to Pin1 or with a notch at the end and center of the package. Often there is both a dot and a notch.



Diodes:

Diodes are one way gates. Current can flow in one direction and not the other. Current flows from the Anode to Cathode. The Cathode end is always marked with a black band around the body of the part, as shown in the above diagram. Small signal diodes are generally in a glass package, while higher current rectifier diodes are in a black plastic package. There is also a special kind of diode called a Zener diode. When a positive voltage is applied to the cathode in respect to the anode, current will start to flow through the diode. The voltage it takes to start current flowing through the diode is dependent of the voltage rating of the diode. The symbol for a zener diode has two extra little lines added to the ends of the vertical line the arrow of the standard diode symbol points to.

Building "Dead Bug" style:

Circuits built on a solid copper ground plane, usually a piece of copper foil laminated to a fiberglass board, and in which the transistors and IC's are mounted with their legs sticking up in the air is called "dead bug" construction. This is because these parts look like dead bugs on their backs. Makes sense, eh? Passive parts are either connected to the the IC and transistor leads, soldered directly to the copper ground plane foil or are suspended in the air. This is a three dimensional construct. This will make more sense later when you view the pictures of the circuits as they are built.

Tools:

Before you can actually start construction, you need some tools. At a minimum, you need a pair of needle nose pliers, side cutters (Dikes) and a soldering iron, with stand. A hot glue gun can be handy here and there. The type of needle nose pliers and side cutters usually sold at hardware stores are too big and clumsy for fine electronics work. You want pliers which come to a fairly fine tip and cutters with a small head to get into tight spaces. A hobby knife such as an Xacto with #11 blade is useful, as are tweezers. A soldering iron with a 25 or 30 watt rating is a good general purpose iron. Get one with an iron clad tip, as this will last longer than an unplated copper tip. If the iron is sitting unused and on, keep a little solder on the tip. If you need to clean the tip of excess solder, only do it just before using. Do not clean the tip and then put it back in the holder and let it sit for any length of time, as the plating will burn off or become tarnished. Be sure to get a soldering iron stand. It is not a good idea to have a hot iron loose on the work bench!

Soldering:

Proper soldering is a fine art, but is not too hard to master. Heat the junction to be soldered together with the tip of the iron for a second or two, then apply the solder from the side opposite from the soldering iron tip. The biggest mistake novice builders make is to use way too much solder. I like to use 0.020" dia solder instead of the more common 0.032" type. The smaller solder allows better control over how much solder is used. You just need enough solder to make the leads stick together or attach to a printed circuit pad. You do not need a big blob of solder at the junction.

With dead bug construction, you will be soldering part leads together, often in the air. After snipping the leads to the required length, put a light coat of solder on the end of each lead to be connected together. This is called "tinning" the lead. Now all you need to do is place the two leads next to each other and heat them again with the tip of the iron and they will stick together. No additional solder should be needed, as some of the solder which is still on the iron tip will flow onto the junction. If the junction is strong enough that a light tug on the parts does not pull then apart, it is strong enough. There is no need to make a strong physical connection between part leads before soldering, such as twisting the leads together, because if you make a wiring mistake and have to fix it, it will be harder to take the connection apart if it is not just held together with solder. Sometimes it is helpful to make a small half loop (hair pin) on the end of a part and lightly compress the loop around another parts lead to hold them together as you solder. This is especially true if the end of one of the parts is not yet secured to something yet.

Part leads should be bent no closer than 1/32" to the body of the part. If you bend the lead right where it comes out of the package, it is likely to break off. This is especially true of transistors and the small Monolithic capacitors. Leads which solder to the copper foil ground plane should have a little foot bent on the end of the leg, about 1/16" is good.

When snipping leads to length, often the cut end will go flying away. Be careful it doesn't fly into your eye or that of an innocent by-stander! This can be avoided by aiming the end of the lead away from you or down towards the work bench.

Wire:

There are places where you will be using wire to make connections between parts. I use heat stripable magnet wire. This wire has insulation which can be soldered through, if enough heat is used. When tinning heat stripable magenta wire, it helps to have a solder blob on the tip of the iron t help conduct heat into the wire. Or you can scrape or burnt off the insulation with a lighter and cleaned up. You will be needing this wire for winding the toroid coils also. Magnet wire can be obtained from Amidon off the web at a pretty reasonable price for a 1/4 lb spool. You will need #32 and #28 wire. You will also need some toroid cores, which Amidon also sells, so might as well get both the wire and cores at the same time. You can also use a small gauge solid insulated wire, such as wire wrap wire, but this type of wire is less common and harder to find these days. You do not want to use large wire from connecting between parts. Only use large sized wire for connecting the power supply up to the board.

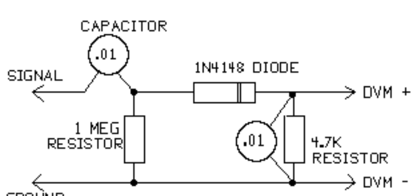
When using magnet wire for connecting to parts or IC leads, first tin the wire to burn through the insulation, then make a small half turn loop on the end. Lightly crimp the loop to the lead to be connected to so the wire doesn't fall off when you solder it in place.

Test equipment:

At a minimum, you will need a voltmeter, which in this day and age will likely be a DMM (Digital Multi-meter). An Oscilloscope and frequency counter would be real handy to have, but your not likely to have these if your just starting out. Instead, a simple diode probe can be made to check for RF voltages and a general coverage receiver used to check for the frequency of oscillators. The S meter (if the receiver has one) can also be handy.

Diode probe:

This can be made on a little piece of copper clad board or made free air style. If you make the diode probe on a piece of copper clad board, cut little square "islands" in the copper foil for the connection points for the capacitor, resistor and diode on the input (signal) side and the junction of the diode, capacitor and resistor on the DVM side. A straight pin can be used as a probe soldered to the capacitor going the the signal input.



Building the MMR-40:

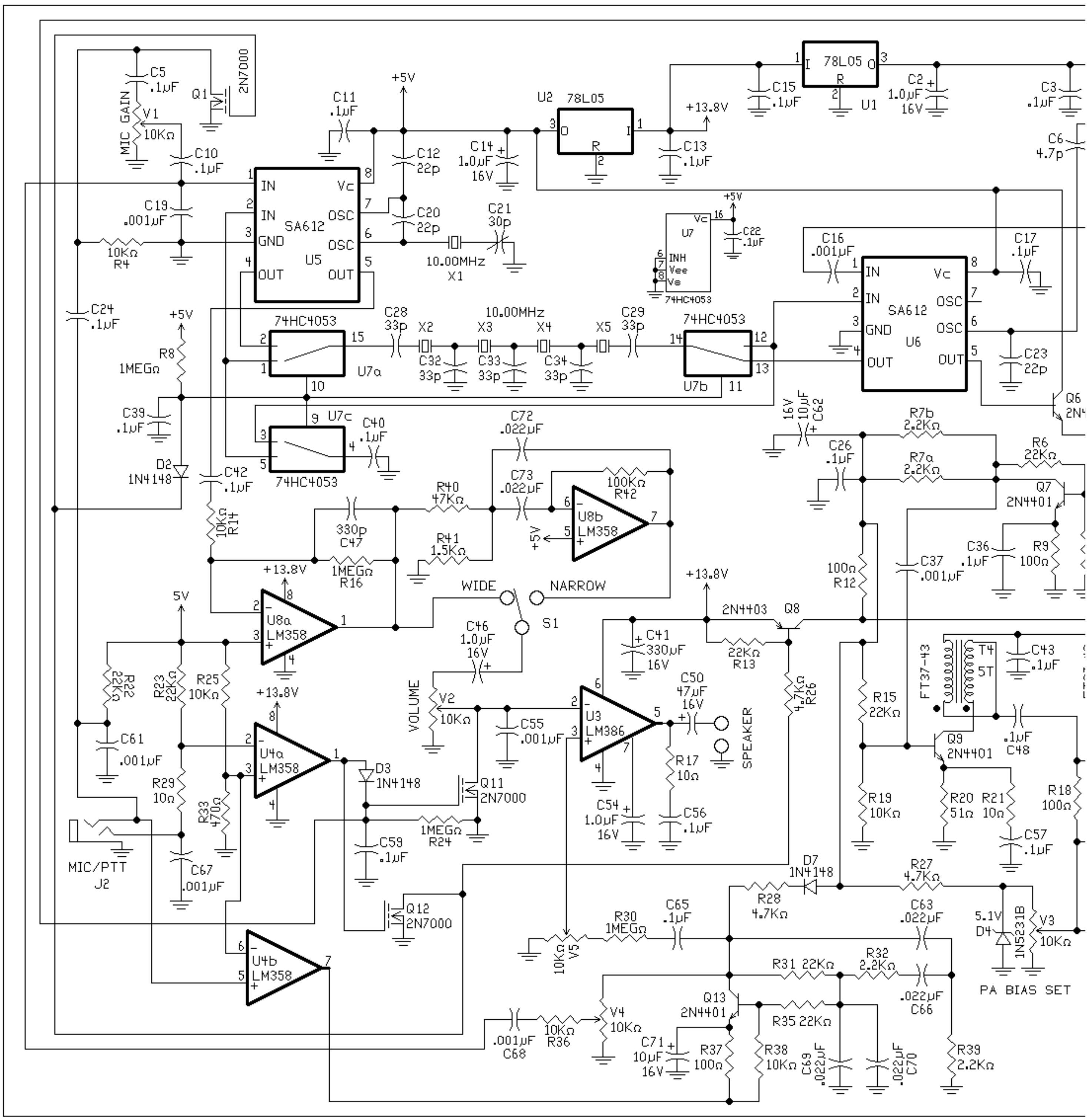
The diagram below shows the overall layout of the board and the inter-connections between parts. It is mostly drawn to scale, but some parts are drawn larger than the actual size for clarity or to be able to label the part number inside the outline. Like wise, the circuit can be built somewhat more compactly

than shown in the diagram. All parts are shown in a horizontal position, but in some places, like when one end of a resistor is connected to the copper ground plane and the other end to a transistor lead, it will make more sense to actually mount the resistor in a more vertical position. Connections to the copper ground plane are shown as red dot and connections which are in the air are shown as blue dots. Wires which connect between parts are shown as blue lines. Some of these wires are shown drawn outside the board outline. You will actually route them near the inside edge of the board. Refer to the schematic to get the part value for each part, as only the part designation label is shown on the diagram.

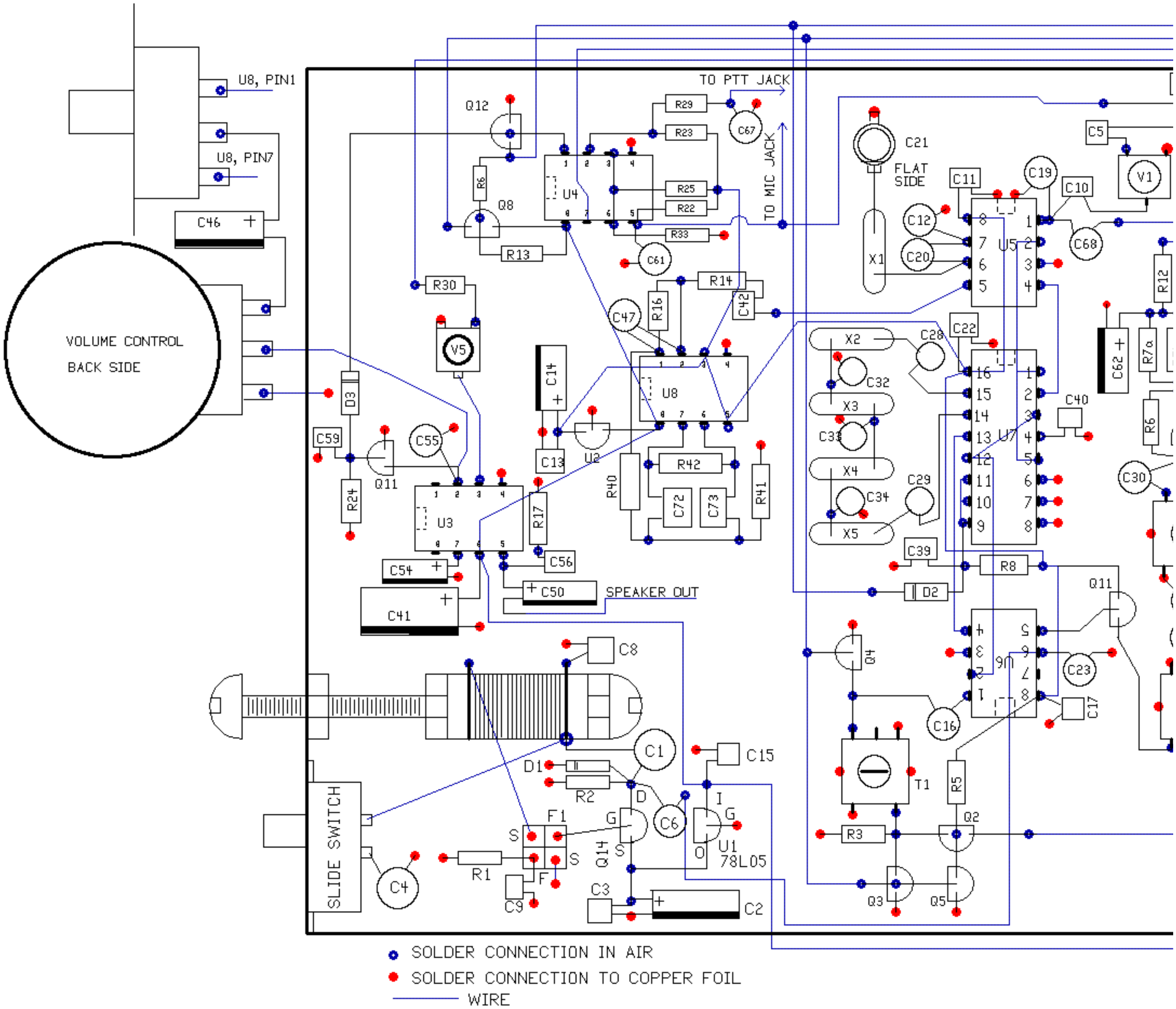
The schematic and overall layout diagram should be printed out for easy reference. If you try to print directly from your browser, you will likely only print the part of the image which shows up on your screen. To print the whole image, save it to a folder first, then open it with an image veiwing program and print from there. Set your printer preferences to print "scale to page" and print in landscape mode to get the largest picture. You will likely want to save this whole HTML document to your PC, so you don't need to be on line to view it.

The MMR-40 circuits will be built in stages which you can test as you go along if you want. The first stage to be built will be the PTO oscillator, then the audio and control circuit, the receiver section and finally the transmitter sections.

Schematic:



Full layout diagram:

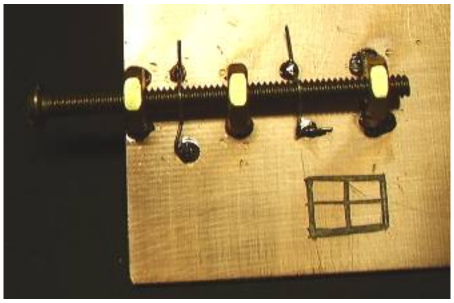


Corrections to the above layout diagram:

R6 is labeled R26 on the schematic. Q11 is labeled Q6 on schematic. C44, which connects across L4, is not shown on the diagram. A wire connecting C43/T4 to C45/T5 is not shown on the diagram. R22 is labeled R32 on the schematic and should be connected to the base of Q13, not the collector as shown in the diagram. The C66 and C63 disignations are reversed, but since these caps have the same value, it is of no real importance. One end of C12 is shown connected to pin 8 of U5 on the schematic. Connecting this pin to ground as shown in the diagram is electrically the same. (On the pcb layout, the by-pass cap on pin 8 of U5 effectively grounds C12). On the schematic, the order in which C56 and R17 are connected are reversed compaired to the layout diagram. Again, this makes no difference as it is the same electrically since these parts are in series. Mechanically, it makes more sense to connect the resistor to ground rathier than the cap.

Building the PTO coil assembly:

The PTO is made from a coil wound on a 0.650" long, # 6 nylon threaded spacer. It is supported by two brass nuts soldered to the copper foil of the board. A third nut at the front edge of the board helps eliminate side to side play in the tuning screw. Thread the three nuts onto the screw. Space the rear two nuts so that the nylon spacer fits between them with a little extra "wiggle" room. Space the third nut at the front of the screw about 1/2" from the middle nut. Position the screw/nut assembly on the copper foil about 1" from the front, right side edge of the board, with the first nut just on the copper at the front edge of the board. Hold the assembly to the copper foil with a couple pieces of solid buss wire as shown in the photo below:



Make sure the screw is square to the front edge of the board, and then solder the nuts to the copper foil. You will need some heat for this! After the nuts cool down, remove the wire holding the screw in place.

You will notice four squares of copper isolated from the rest of the board in the above photo. Use a sharp hobby knife to first make a shallow cut to mark the outline of the squares. Then, holding the blade at a slight sideways angle, cut away the copper along the first cut. Then make a third cut on the other side. Repeat as needed to open up an area clear of copper. Use an ohm meter to verify you have removed all the copper between the islands. These four "islands" or pads will be used to mount the L2 coil portion of the PTO circuit. You will need to cut this type of small island pad here and there so that leads of parts which need some mechanical strength but are not connected to the ground plane can be soldered to.

Although not shown on the above photo, the copper foil under where the PTO coil will mount between the last two nuts also needs to be removed. Define the area to be removed by cutting a line into the foil with your knife. Now use your soldering iron the heat up the copper at a corner point. The heat will help de-laminate the copper from the fiberglass board underneath. After a few seconds of heating, work the edge of the foil up with the tip of your knife. Once you roll up the corner a little, you can grab onto it with your needle nose pliers and peal back the foil. Continue adding heat where the copper meets the board or the foil will not come off cleanly in one piece.

Now you can wind the PTO coil on to the Nylon spacer. Make end stop/connection points for the coil wire with a turn of solid buss wire with the two ends twisted together. Position these about 1/4" from the each end of the spacer. See photo of finished coil below.

Thread the screw into the spacer so you have something to hold onto. Snug the spacer up tight to the head of the screw. Now wind 39 turns of # 32 magnet wire onto the spacer. It is easiest to spin the spacer between your fingers and keep some tension on the wire with your other hand as you do. Tin and wrap the starting end of the wire to the wire ring you put on the spacer at the head of the screw end and solder the wire to it. (be quick and use as little heat as possible so as not to melt the wire into the Nylon) As you wind the coil, snug up the turns to each other with the thumb finger nail. Try not to overlap turns. At the end of the required number of turns, (which can be off a few turns one way or the other, so don't worry too much about losing count), wrap the end of t he coil wire around the tab of the wire ring at the bottom of the spacer and solder the coil wire to it.

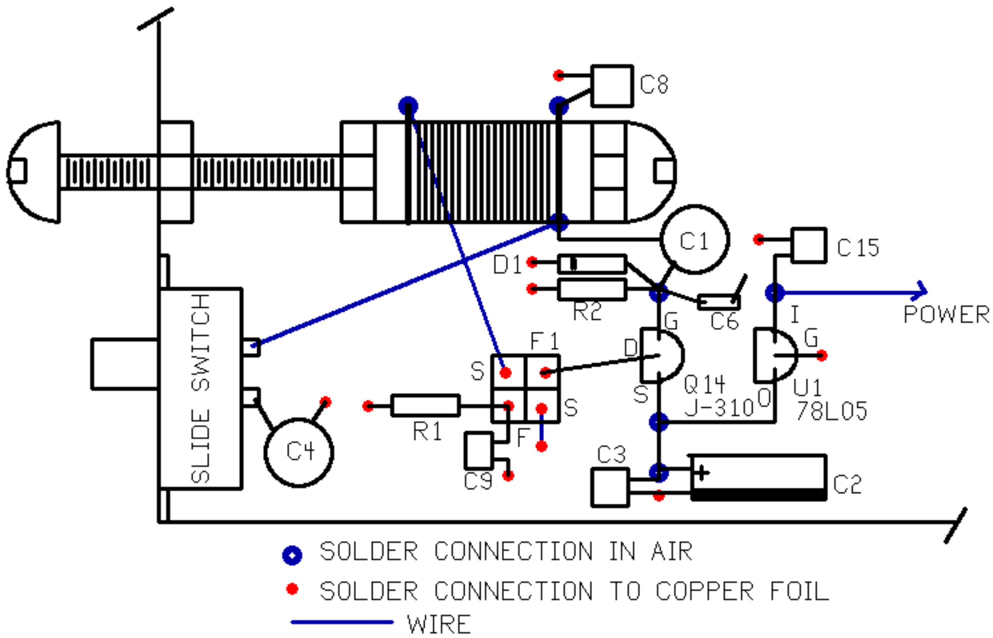
---The finished PTO coil

Now remove the screw and place the spacer between the rear two nuts soldered to the board. Thread the screw back into the nuts and into the spacer. It is likely you will have to turn the spacer in order to find the spot which will allow the screw to enter the spacer threads smoothly. Do not try to force it, though it should be a little stiff. Once you get it so the screw goes in and out of the spacer with out undo force, secure the back end of the spacer to the end nut with a 1/4", # 6 Nylon screw. If needed, snug the spacer up to the rear nut so that it does not spin when the screw is moved in and out.

A knob for a 1/4" shaft can be added to the screw by first cutting off the head of the screw. A 1/4" or 1/2" long, 1/4" dia threaded # 6 brass spacer can then put on the end of the screw. The end of the spacer can be soldered to the screw to hold it in place. A knob can then be put over the 1/4" dia spacer.

Building the PTO oscillator circuit.

Now comes the nitty gritty of actually wiring up the circuits. We start with the PTO oscillator. The J-310 J-FET and 78L05 regulator are mounted with their legs in the air, the top of the plastic package flush to the board. All the transistors are mounted this way in the diagrams. Bend the leads out as shown, making the right angle bend a little above where the leads come out of the package. If you bend them right where they come out, they will likely break off. The diagram below shows how the parts are connected. For clarity, some of the parts are shown laying down or at an angle, while they should be mounted in a more vertical position as you can just make out in the fuzzy picture of the completed circuit. Connections made to the copper foil ground are shown as a red dot and connections which are floating in the air are shown as a blue dot. Pat values are not shown, only the part number. Refer to the schematic for part values. It is a good idea to use a highlighter to mark off the parts as you put them in place and the connections you make, as to keep track of what has been done and where you stand.The L2 coil is not shown mounted in the diagram, but it will be soldered to the four pad "island" box you cut into the foil. C6 has one lead just floating in the air for now.



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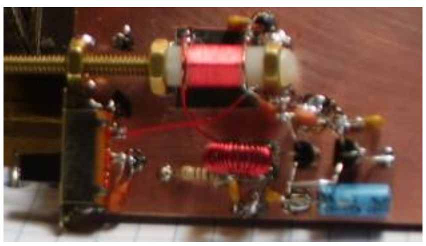
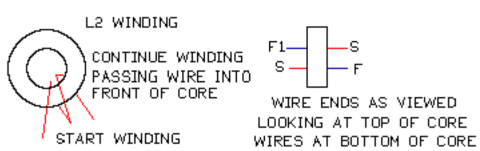


Winding the L2 coil:

The L2 coil needs to be wound in a specific way so that the phasing of the oscillator feedback turns come out to the correct pads on the board. If the ends of the feedback winding are reversed, the oscillator will not work. The red T37-2 toroid core is wound with #28 magnet wire. Start by passing the end of the wire up through the hole from the back side of the toroid, as seen as you hold it in one hand. Leave about a 1/2" long pig tail sticking out of the hole. This is the first turn, as a turn is each time the wire passes through the hole in the core.

Now continue winding by passing the long end of the wire down through the hole from the top side of the core, as shown in the diagram below. Wind in a counter clock wise direction. The wire should be wound snug, but not real tight against the sides of the core. Wind 29 turns and then make a small loop about 1" long and continue winding five (5) more turns. This will be the feedback winding. Snip the loop to separate the main winding (S) and the feedback winding (F). Tin the wire ends, leaving about 1/4" lead length from the core. Position the core over the four pad square on the board and solder the main (S) winding to the pads labeled "S". Solder the remaining two wires to the pads labeled "F" and "F1".



Testing the PTO oscillator:

Now that the PTO oscillator has been wired up, we can test it to make sure it works. A 9 volt radio battery can be used to power the oscillator for now. Connect the plus lead (RED) of a 9 V batter clip to the junction of C15 and the "I" lead of the 78L05 regulator. Connect the black lead of the battery clip to the copper foil. Attach the battery to the clip to power up the circuit. First use a volt meter to make sure there is 5 volts (+/- 0.25V) on the output of the regulator U1 (lead labeled "O"). The easiest way to see if the oscillator is working is with an Oscilloscope and to check the frequency with a frequency counter, but you probably don't have either of these. Hopefully you have a general coverage receiver which will tune between 2 and 3 MHz. Using a clip lead or short piece of wire as an antenna and place near one of the coils, you should find a strong signal somewhere between 2.7 and 3 MHz. Exactly where depends on how far the tuning screw is inserted into the PTO coil and if C4 is switched in or out of the circuit. If you can't find a signal, then it is likely you have the S and F windings reversed. The oscillator is probably working, but at a much higher frequency than it should be. Hopefully you didn't make any wiring errors this early in the game, but since your just starting out, it is possible and the wiring double checked. The diode probe connected to the flying end of C6 can also be used to tell if the oscillator is working.

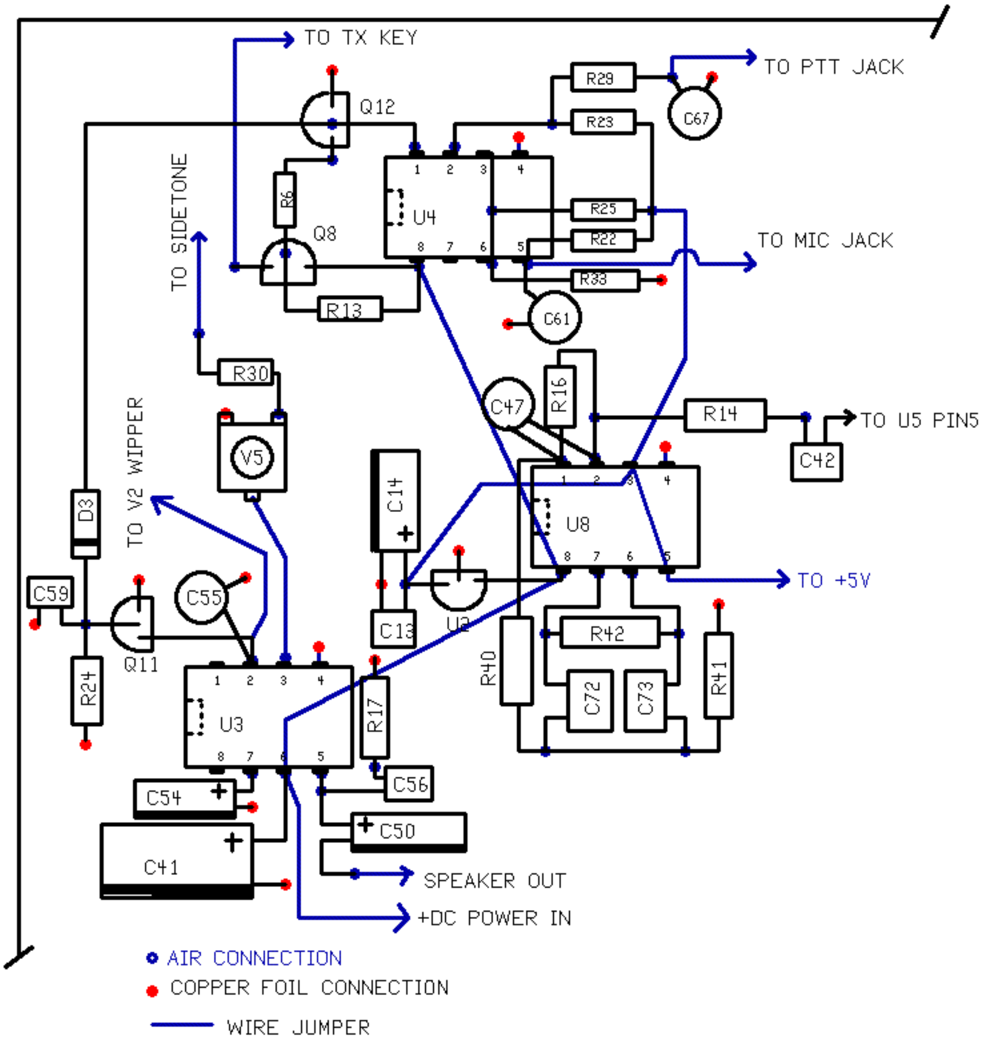
If you do find the signal in the proper frequency range, you can now fine tune the range of the oscillator. With C4 switched out of the circuit and the tuning screw fully inserted into the PTO coil, the frequency should be no higher than 3.000 MHz. This will correspond to 7.000 MHz when the rig is done. The frequency can be fine tuned by moving the turns on L2. Spreading the turns apart will increase the frequency and pushing them closer together will lower the frequency.

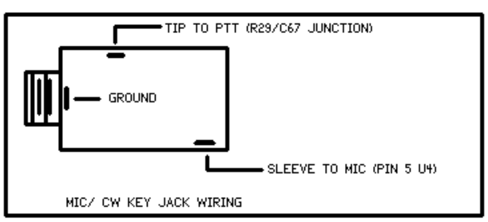
Audio and control circuits:

Here is where the circuit starts to become a little more complicated. Start with the U4 op amp near the front left side of the board and add parts to it. Then go over to the U8 op amp and finish with the U3 audio amp. The first part to be mounted will be the IC package. First ground Pin 4 to the copper foil by using a resistor or capacitor lead clipping to make the connection. Tin the copper where the lead will attach. Bend one end of the lead at a right angle and

tack it to the copper where you pre-tinned. Then tack solder the lead to the side of Pin 4. This will hold the IC in place. Be very careful to mount the IC the right way. Since it is upside down, you have no way to verify the pin 1 end and once you start adding parts to the pins, it will be difficult to correct if it is not positioned correctly. Now start adding the rest of the parts. For clarity, the position of the parts are not quite where they will ideally end up for a compact assembly, but should give you an idea of where they go. Before mounting V5, cut copper islands from the foil under the un-grounded legs. (Blue dots)

NOTE: R6 is labeled R26 on schematic.





You might want to wire up the mic/key jack now and can be hot glued to the front right corner of the board for now so it stays in place.

Testing the audio and control circuits:

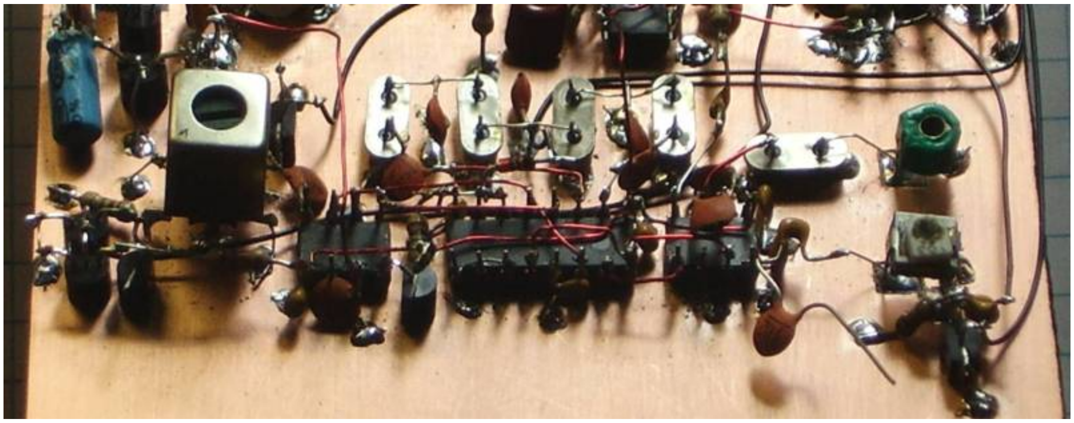
You can test the audio and control circuits using power from the 9 volt battery you used for testing the oscillator. The reason for using a 9 volt battery instead of a more robust power source is that if there is a problem, it is not likely the 9 volt battery will cause any damage.

Before you hook up power to the circuits, connect a small speaker the end of C50 labeled "speaker out" and tack a 1 ufd electrolytic cap between Pin 3 of U3 and Pin 7 of U8, with the + side of the cap to Pin 7 of U8. Now connect up the battery clip, Red + lead to Pin 6 of U3 and the black - lead to ground (the copper foil). Touching the floating end of C42 should result in a very loud buzz in the speaker.

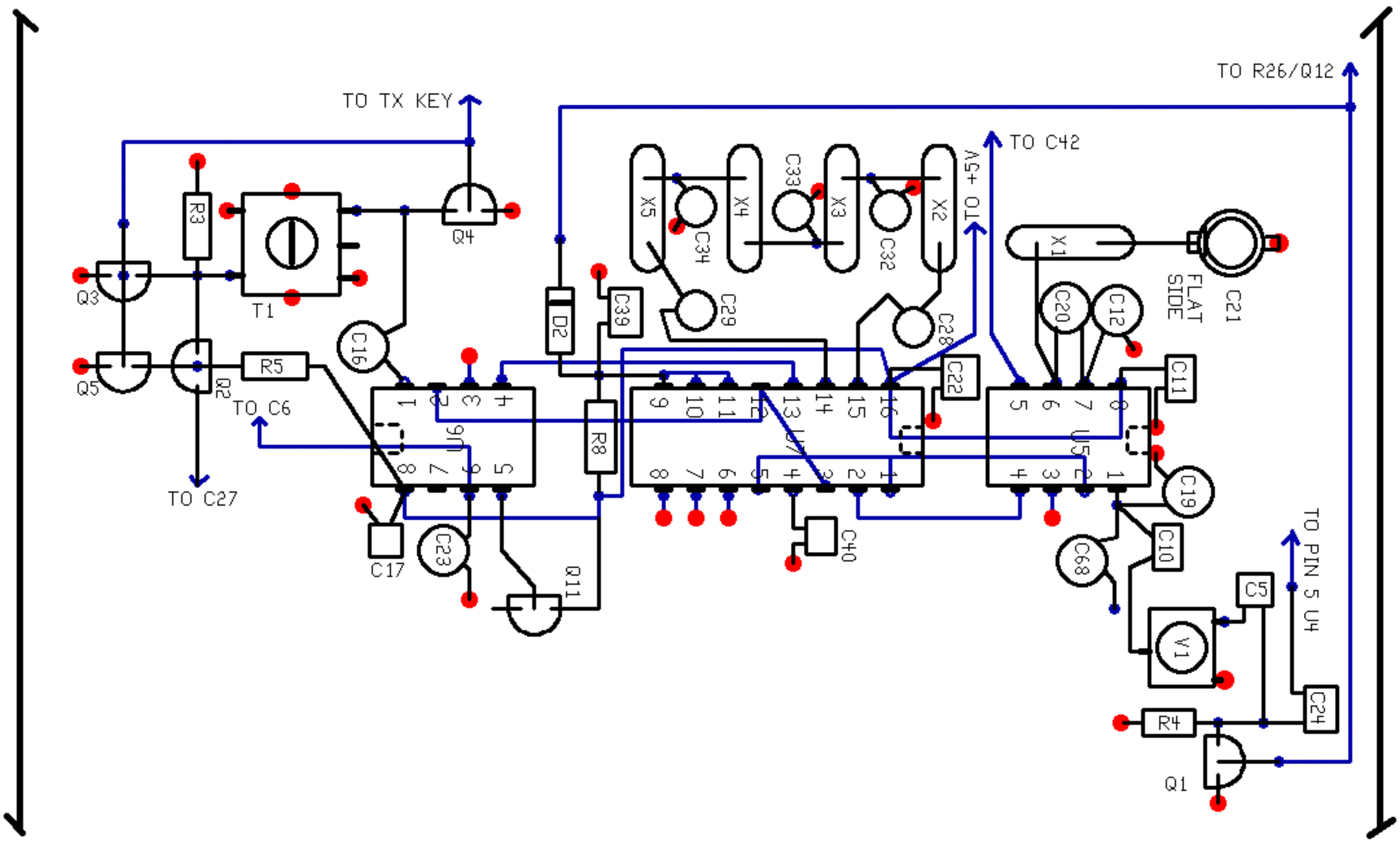
Grounding the junction of R29 and C57 (this is the PTT input) should make the voltage on pin 1 of U8 go from zero (0) volts to near 9 volts. If you touch the end of C42, you should not hear a faint or low volume buzz in the speaker. Grounding pin 5 of U8 should make the voltage on pin 7 go from near 9 volts to zero (0) volts.

If you pass these three tests, your doing very good and can move on. If not, double check your wiring and soldering and keep trying until it works. Before moving on to the next section, connect a wire between pin 6 of U3 to the C15/U1 junction labeled "power" so the PTO will get power after the next section is completed.

Receiver RF sections:



Front of board towards top.

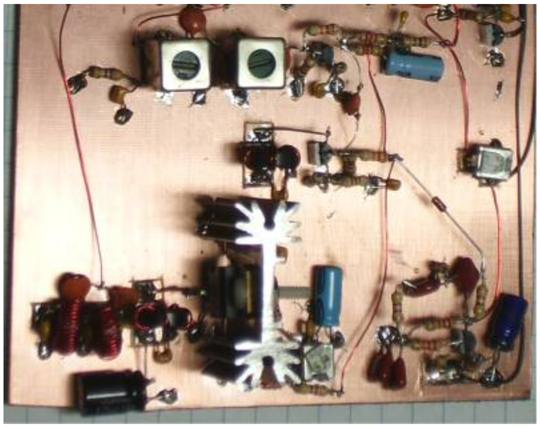


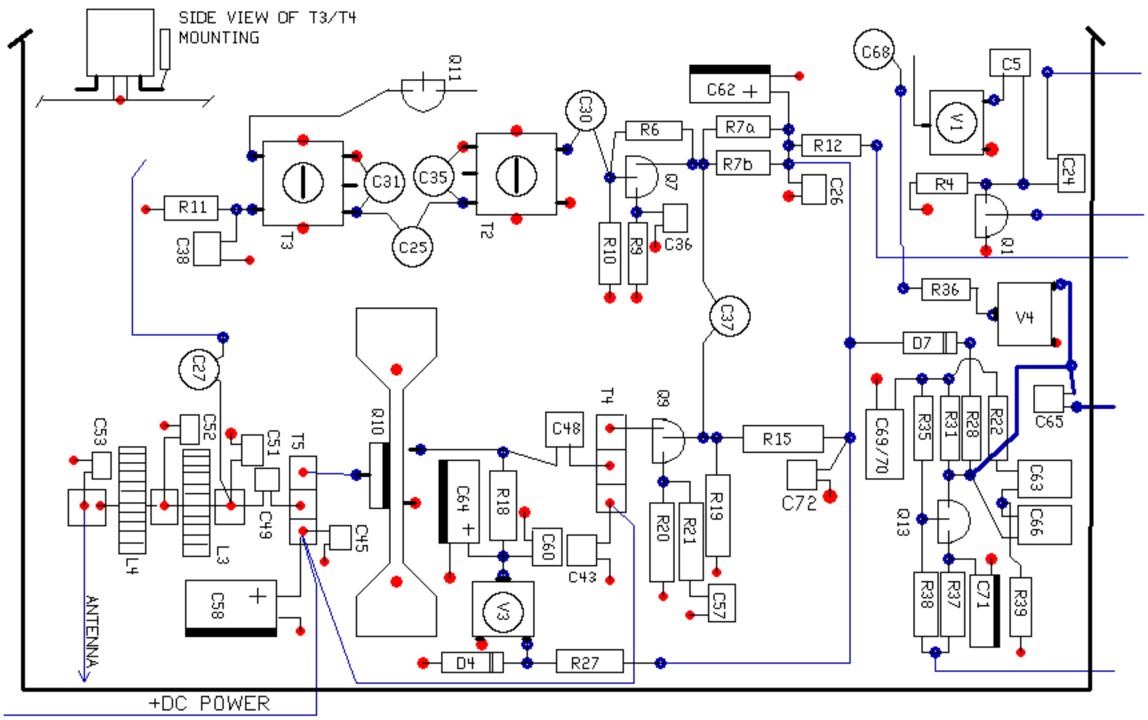
The crystal cans can be soldered to the copper foil to hold them in place. Pre-tin the sides of the round ends of the crystal can and tack these ends to the board. Note that Pin 1 of U6 faces opposite direction of that of U7 and U5. Cut Island pads under ungrounded leads of V1 and C21. Leads of IF transformer T1 can be bend at right angle so they don't touch the copper foil. Make these bends about half way down the length of the pin. Solder the mounting tabs of the IF can to the copper foil. Connect pin 8 of U6 (wire end labeled "TO +5V") to pin 5 of U8. Once the parts shown above have been wired up, wire up the volume control and S1 Wide/Narrow switch and attach the speaker. Make about a 1/4 turn from the factory setting of C21. If you look closely into the hole on top of C21, you will see one end of the screwdriver slot has a slight arrow shape. When the arrow faces the flat side of the package, it is set to minimum capacitance, when it faces the round end, it is at maximum. Do not connect the wire labeled "TO TX KEY" back to Q8 near the front of the board. Instead, ground this connection for now.

NOTE: Q11 is labeled Q6 on the schematic.

The receiver should now be functional. Connect an antenna to the leg of Q2 labeled "TO C27" and you should be able to tune in stations or hear band noise. You can continue to use the 9 volt battery to power the circuits for now. Adjust the slug in the top of T1 for best signal strength. Usually turning it "clock wise" 1/2 to 1 turn will do it.

Transmitter sections:





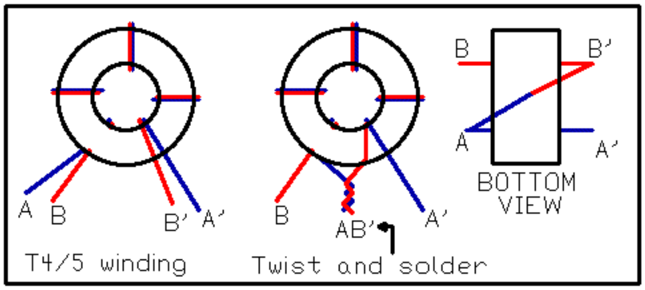
Start assembly with the T3 and T4 IF transformers. C31 and C35 should be mounted to the transformer leads before you solder the cans to the board. Place the body of the cap flat to the side of the can. This will allow spacing the transformers closer together than what is shown in the diagram. Don't forget to bend the transformer leads out at a right angle, making the bend about 1/2 way down their length. Once the transformer cans have been soldered to the board using the ends of the mounting tabs, tack the C25 cap in place between them.

Cut Island pads into the copper foil to provide a place to mount T4 and T5 as shown by the three box outline. Make real sure these are isolated from the sourounding copper ground plane, as these will have the full DC supply voltage on them. A short here to ground could damage your power supply. After T4 and T5 have been mounted, double check for shorts with your ohm meter. Also cut pads under the un-grounded leads of V3 and V4 (leads with blue dots). Build everything to the right of Q10 and the heatsink. Refer to the overall layout diagram to make the connections shown going off the right edge of the board back to the points they need to connect to near the front of the board.

NOTE: R22 is labeled R32 on the schematic and is connected to the base (center lead) of Q13, not the collector as shown in the diagram. The C63/C66 designations are reversed from the schematic. C44, connected across L4 is missing from the diagram.

T4, T5 winding:

T4 and T5 are Bi-filler wound transformers. This means two wires are wound on the core, side by side or lightly twisted together. A total of five (5) turns is used. (remember, a turn is each time the wire(s) pass through the hole in the core. T4 and T5 are wound on a ferrite core (black). Once you have wound the core, you must identify the common ends of each wire and position them so they are opposite each other. Tin or strip the end of the wires and use an ohm meter to identify the common ends of the two wire. Then take one end of each wire which is diagonal from each other and twist these together and solder. This is the center tap of the transformer and produces the correct phasing of the turns. See diagram below: The center tap will connect to the center "island" in the three pad pattern shown in the wiring diagram above.



Use a short piece of wire to ground Pin 5 of U4 (TO MIC JACK) This will put the circuit into CW mode. Clip a clip lead or attach a length of wire to the Junction of R29 and C67 (TO PTT JACK) Grounding this wire when required will put the circuits into transmit mode. Re-connect the speaker to the board. Connect a 12 to 14 volt power supply to Pin 6 of U3 near the front of the board. Make sure you also have a wire connecting from Pin 6 of U3 to the C43/T4 junction pad.

Turn the power supply on. Ground the PTT wire or clip lead. You should hear the 600 Hz side tone in the speaker. Adjusting V5 will change the volume. If you do not hear the side tone, make sure Pin 7 of U4 is near 0 volts and that it is connected back to R37 and R38. Review the wiring of the tone oscillator (Q13 and associated parts) to make sure they are connected correctly. Once you verify the side tone is working correctly, you can disconnect the speaker as listening to the side tone for any length of time can be annoying.

The next step is to peak the transmitter band pass filter, the T2 and T3 IF transformers. For this, you will need the diode probe. Build it now if you have not already done so. The tuning of T2 and T3 should be made near the center of the tuning range of the PTO. Remove the screw from the PTO coil and make sure the band select switch is set to remove C4 from the circuit. Connect the "signal" input end of the probe to the R18/C48 junction. Key the transmitter by grounding the PTT jack lead. Adjust the slugs on the top of T2 and T3 for the maximum amount of voltage as shown on you voltmeter (which is connected to the diode probe). You should not have to turn the slugs much, again like T1, 1/2 to 1 turn clockwise should do it. The adjustment is interactive between the two transformers, so go back and forth a couple of times to find the best peak. You should be able to get a 5 to 7 volt reading on the voltmeter.

Now turn V4 fully counter clock wise. This will turn off the 600 Hz tone to the balanced modulator. The voltage from the diode probe should go to near 0 volts. If it does not, adjust the C21 BFO trimmer slightly until it does.

The final transmitter circuits:

The heat sink has mounting tabs on the bottom. These will solder to the copper to support the heat sink and stand it off the board so that that leads of Q10 can be bent to make the connections to. No insulating washer is needed and a metal screw used to hold the power FET to the heatsink, but be careful not to nick the anodizing on the heat sink, or you could make a short. After you mount the heatsink and Q10, double check with your ohm meter to make sure the metal tab of Q10 is not shorted to ground (the copper foil, as you must know by now!)

L3 is wound with 15 turns of # 28 wire on the red T37-2 toroid core.

L4 is wound with 25 turns of # 28 wire on another red T37-2 core.

Be very careful counting the number of turns. Remember, each time the wire passes through the center of the core, it is counted as a turn. If you are off by just one turn too many or too few, it will drastically affect the amount of output power from the transmitter.

Final tests:

The first thing to do is set the bias current of the PA, Q10. Wire a jumper from the T5/C45/C58 junction over to the T3/C43 junction and connect the positive lead for the power supply to the T5/C45/C58 junction. Solder the negative lead for the power supply to the copper in this same area.

Make sure V4 is still fully counter clockwise or better yet, disconnect C48 from R18 so there is no signal going to Q10. Turn V3 fully counter clock wise. Power up the board, put it in transmit mode by grounding the PTT input. Measure the voltage at the V3/D4/R27 junction. It should measure just over 5 volts. (5.1 to 5.2) If it reads about 0.6 or 0.7 volts, D4 is installed backwards. If it reads much more than 5 volts, you mixed up the zener diode with one of the 1N4148 diodes.

Set your DMM to the 20 amp scale and connect it in series with the positive power supply lead. The red probe will go the plus side of the power supply and the black probe to the positive DC input to the board. There is probably a seperate jack for the red probe on the meter for using the 20 amp current scale of the meter, be sure to move the probe to this jack. It is also a good idea to have a 2 amp fuse in line with the power supply lead.

Turn power onto the board, key the transmitter by grounding the PTT input and note the current being drawn. It will likely be about 190 ma. With the 20 amp scale, the meter will read 0.19 or there abouts. Now turn V3 clockwise until the current goes up by about 10 ma, an increase of one digit on the meter. You will probably find the setting of V3 to be slightly past the mid point of its range. (Which is where it is set from the factory). Be careful when making this adjustment. If you turn V3 up too high, the supply current can go up to as much as the power supply can deliver and that could damage the power supply or Q10. That is why it is a good idea to have a 2 amp fuse in line.

Un-ground the PTT input and remove power from the board. Reconnect C48 if you disconnected it.

You are now nearly done! Only one last thing to do, hook up the antenna jack and check the power output. The center pin of the antenna jack connects to the point labeled "To antenna". If the connection to the jack is less than an inch or two, just run a wire from the center pin to the antenna connection point on the board and another wire to the copper ground foil near that point. If the run is 2 to 6 inches, twist the wires together to the jack. No need for coax for this short a connection.

Connect up a wattmeter and 50 ohm dummy load to the antenna jack. Hopefully you watt meter can read down to 5 watts with reasonable accuracy. You should still have the board configured for CW mode by having the mic input grounded, V4 set fully counter clock wise and the PTO frequency set to mid range. You can remove the DMM from the power supply leads if this is still connected.

Apply power to the board and key the transmitter. At this point, there should be no power output. Turn V4 clock wise and you should start to see power output. Keep turning up V4 untill the power output stops going up. You should see at least 5 watts when it does. The amount of power output can be optimized by "tweaking" the spacing of the wire around the L3 and L4 cores. If you have the wire more or less evenly spaced around the core, try pushing some of the turns closer together on the L3 coil first and see how this changes the power output. If you get more power output, keep moving turns closer

together until the power output starts going down again. Then try the same thing with L4. With a 13.8 volt supply, you can get the power output as high as 8 watts with a little fussing with the coils. Also try touching up the tuning of the T2 and T3 transformer slugs to get the most power output.

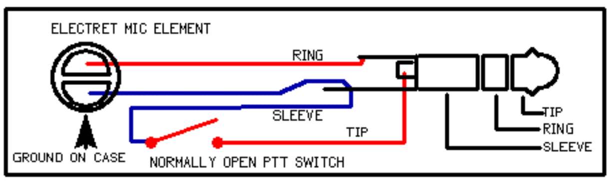
Power output will vary some with the frequency of the PTO. You should peak up the power output around the frequency you think you will be operating the most often. You probably want to get the most amount of power output in the voice segment of the band, as this I where you want to get the most you can. If the power out is somewhat less at the low end of the CW band it will still be very effective.

Now the board is finished, all tuned up and ready to go! The last thing to do is find a suitable box to put the board in, drill the holes for the jacks, controls, ect and mount the board into it. The D6 diode shown on the schematic but not yet wired to the board should go between your DC power jack and the +DC input to the board for reverse polarity protection. With out this diode, if you hook power up backwards, the board will draw as much current as you supply can deliver until something burns up!

Making a Microphone:

The MMR-40 uses an Electret condenser microphone element. A dynamic mic will not work. Condenser mic elements can be found in a number of consumer electronic products such as cordless phones, answering machines, hands free cell phone mics, computer mics and most anything which uses a mic. They can also be bought new for a dollar or so. A CB mic would be the simplest thing to use, though there are all kinds of possible ways to make a desk mic for the mechanically inventive.

Electret elements are small silver cylinders. There are two connections on the back side of them. Generally, these look like half moons. If you look closely, one of these half moons as a connection leading to the shell of the mic. This is the ground. You can also use your ohm meter to verify this is the pad connected to the shell. Wire the mic element and PTT switch to a 3.5 mm stereo plug as shown below.



Setting the mic gain:

Setting the mic gain can be a little tricky. If set too low, you will have low power output and poor sounding audio. If set too high, your signal will "flat top" and cause splatter, along with poor sounding audio. This is worse than having the audio level too low. The problem with setting the mic gain is your watt meter reads the average power, not the peak power (though some meters have a peak power reading mode). With normal speaking, the watt meter will read about 1/3d of the power produced with CW mode. A louder than normal speaking level "AHHHHH" into the mic will produce a power output of close to the CW power. Say these "AHHHH's" into the mic and turn V1 clockwise until the power output is no longer increasing, typically about 4-5 watts depending on what the CW power output was. Now back off on the setting of V1 just a little.

Working CW.

When using the MMR-40 in CW mode, all you need to do is plug a monaural phone plug into the mic jack. This will ground the mic input and allow the side tone generator to be enabled when keying with the PTT input. You can use either the Wide or Narrow audio filter position, though most of the time you will want to use the narrow setting. When responding to an other stations "CQ", you should try to match the tone of the received signal to the side tone frequency of the MMR-40. This will make your transmit frequency match the other stations. The Narrow filter setting helps in making this tone match, as the filter peak response is the same frequency as the MMR-40 side tone.

Parts list:

All part numbers are for Mouser.com, unless otherwise noted.

Part designator (quanity) value --- Part number

Resistors

R17, R21, R29, (3) 10 ohms --- 660-CF1/4C100J

R1, R3, R20 (3) 51 ohms --- 660-CF1/4C510J

R9, R12, R18, R37 (4) 100 ohms -- 660-CF1/4C101J

R11, R33 (2) 470 ohms --- 660-CF1/4C471J

R41 (1) 1.5K --- 660-CF1/4C152J

R7a, R7b, R32, R39 (4) 2.2K --- 660-CF1/4C222J

R26, R27, R28, (3) 4.7K --- 660-CF1/4C472J

R4, R10, R14, R19, R25, R36, R38 (7) 10 K --- 660-CF1/4C103J

R5, R6, R13, R15, R22, R23, R31, R35 (8) 22K --- 660-CF1/4C223J

R40 (1) 47K --- 660-CF1/473J

R42 (1) 100K ---- 660-CF1/4C104J

R2, R8, R16, R24, R30, (5) 1 Meg --- 660-CF1/4C105J

V1, V4, V5, V3 (4) 10K trimmer --- 652-3318P-1-103

V2 (1) 50K pannel mount volume --- 313-1500F-50K

Capacitors

C6, C25 (2) 4.7 pfd NPO --- 140-50N2-4R7C-TB-RC

C12, C20, C23, C44 (4) 22 pfd NPO --- 140-50N2-220J-RC

C1, C4, C28, C32, C33, C34, C29 (7) 33 pfd NPO --- 140-50N5-330J-RC

C31, C35 (2) 47 pfd NPO 140-50N5-470J-RC

C8, C47, C51, C53 (4) 330 pfd C0G mono --- 80-C315C331J1G

C52 (1) 680 pfd C0G --- 80-C315C681J1G

C16, C19, C27, C30, C37, C55, C61, C67, C68, (9) .001 ufd disk --- 140-50P2-102K-RC

(25) 0.1 ufd X7R mono--- 80-C320C104K1R (get a few extra of these, just to have around)

C3, C5, C9, C10, C11, C13, C15, C17, C22, C24, C26, C36, C38, C39, C40, C42, C43, C45, C48, C49, C56, C57, C59, C60, C65

C21 (1) 30 pfd trimmer cap --- 659-GKG30015

C63, C66, C69, C70, C72, C73 (6) .022 ufd Film --- 140-PF2A223J

C2, C14, C46, C54, C64 (5) 1.0 ufd 25V --- 140-XRL25V1.0-RC

C50 (1) 47 ufd 16V ---- 140-XRL16V47-RC

C62, C71 (2) 10 ufd 16V --- 140-XRL16V10-RC

C41, C58 (2) 330 ufd 16V ---- 140-XRL16V330-RC

Semiconductors

U5, U6 (2) 771-SA612AN/01

U1, U2 (2) 511-L78L05ACZ

U3 (1) 513-NJM#386D

U4, U8 (2) 512-LM358AN

U7 (1) 511-74HC4053N

Q1, Q2, Q3, Q4, Q5, Q11, Q12 (7) 512-2N7000

Q6, Q7, Q9, Q13 (4) 863-2N4401G

Q8 (1) 863-2N4403G

Q10 (1) 512-IRF510A

Q14 (1) 512-J310

D1, D2, D3, D7 (4) 512-1N4148

D4 (1) 512-1N5231B

D6 (1) 863-1N5817G

T1, T2, T3 (3) 10.7 MHz IF transformer --- 42IF222

X1, X2, X3, X4, X5 (5) 10.000 MHz crystals --- 815-AB-10-B2

S1, S2 (2) SPDT slide switch, panel mount --- 629-GS1150511 - get 3 if you want a power on off switch.

(1) 4X6" copper clad board ---- 590-509

(1) 1/4" #6 Nylon screw --- 561-F632.25

(1) #6 Nylon spacer --- 561-L6.625

(1) Heat sink --- 567-637-10ABP

J2 (1) 1/8" stereo jack --- 161-3507-E

J1 (1) panel mount BNC jack --- 571-5227755-2

(1) optional DC power jack 2.5mm pin --- 163-MJ22-EX or 2.1mm pin 163-4304-E

These parts are from Amidon.com

T4, T5 (2) FT37-43 ferrite core

L2, L3, L4 (3) T37-2 Red powdered iron core

(1) 1/4 lb spool of #32 magnet wire, thermalize

(1) 1/4 lb spool of #28 magnet wire, thermalize.

From hardware store or smallparts.com

(3) # 6 brass nuts

(1) # 6, 2" long brass machine screw

New Ratio Detector Simplifies FM Receiver Design

This article was published by RCA in Broadcast News, Vol. No. 42, January, 1946.

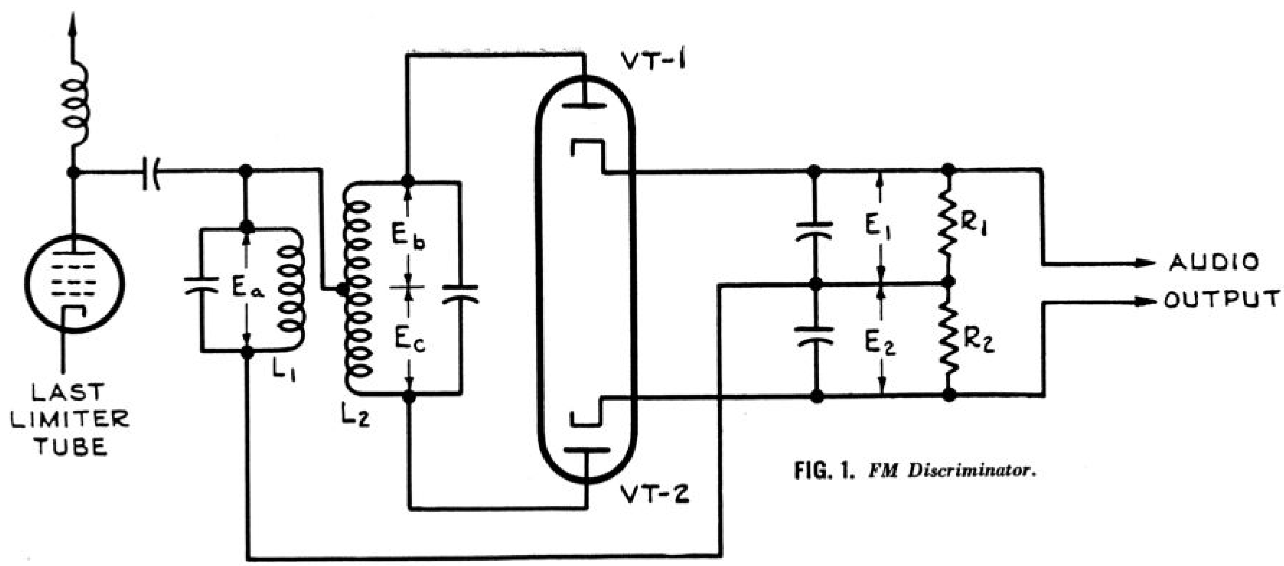


FIG. 1. *FM Discriminator.*

NEW RATIO DETECTOR SIMPLIFIES FM RECEIVER DESIGN

by STUART W. SEELEY
Manager, Industry Service Section
RCA Laboratories

Until recently it had been more or less taken for granted that any detector in a frequency modulation receiver (usually called the discriminator) would also respond to amplitude variations. For this reason limiters were used ahead of the discriminator in most FM sets in an attempt to "level off" the applied signals before they were detected. Limiters need large signal amplitude for proper operation which in turn requires excessive preceding amplification with attendant regeneration and over-load difficulties. Furthermore, limiters often act as phase modulators converting peaks of interference into frequency variations, thus indelibly impressing them upon the program content of the received signal.

Recent circuit developments made in RCA Laboratories have produced simple FM discriminators insensitive to amplitude modulations and amplitude interference. There are many variations of these new discriminators and they give a new concept of the design of FM receivers. With them it is no longer necessary to provide the extremely high intermediate-frequency amplification for satisfactory noise "quieting," for limiter stages are

a function of frequency, rather than the difference of those potentials as has been done in the past. The ratio of those potentials remains constant in the presence of amplitude variations whereas the difference varies with the amplitude.

The diagrams above afford an interesting comparison of the operation of the ratio detector and that of the standard FM discriminator. (Note: In order to make the comparison simpler these circuits have been drawn somewhat differently than usual: however, the basic circuits have not been changed.)

Figure 1 is a simplified diagram of the discriminator circuit widely used in prewar FM receivers. Fundamentally, this is an adaptation of the so-called Seeley Discriminator which was first used in AFC circuits (D. E. Foster and S. W. Seeley, Automatic Tuning, Simplified Circuits, and Design Practice, PROC. I.R.E., 25, 289, 1937).

The operation may be briefly described as follows: L_1 and L_2 form an interstage coupling transformer tuned to the mean or "carrier" frequency. The r-f voltage E_a in the primary induces a voltage in the secondary which, for purposes of discussion, may be divided into two components E_b and E_c. The r-f voltage in the secondary is fed to the anodes of a pair of diodes as shown. However, there is also a direct connection from one side of L_1

fication for satisfactory noise quieting, for limiter stages are omitted entirely.

Furthermore, while they are performing their normal function of detecting frequency modulations, they also produce the correct amount of automatic volume control voltage to regulate the amplification of preceding tubes. Thus they prevent over-load and cross-talk as well as phase modulation by amplitude interference in those stages and result in much improved receiver performance.

The name Ratio Detectors for these new FM circuits was derived from the fact that they utilize the ratio of two developed intermediate-frequency potentials whose relative amplitudes are

to the center of L_2. This places L_2 directly in the cathode return circuit of the diodes. Thus, the total r-f voltage on the anode of the first diode (VT-1) is $E_a + E_b$. These voltages must, of course, be added vectorially. Figures 3 and 4 show the effect of this addition. When the frequency of the r-f voltage from the limiter is equal to the resonant frequency of the tuned circuit, the voltage in the secondary is 90° out of phase with that in the primary, and voltage addition is as shown in Figure 3. The r-f voltages E_1 and E_2, which are fed to the diodes, are equal and the d-c (or a-f) output of the diodes are also equal. Since the output connections of the diodes are opposed, no voltage will appear at the audio output terminals.

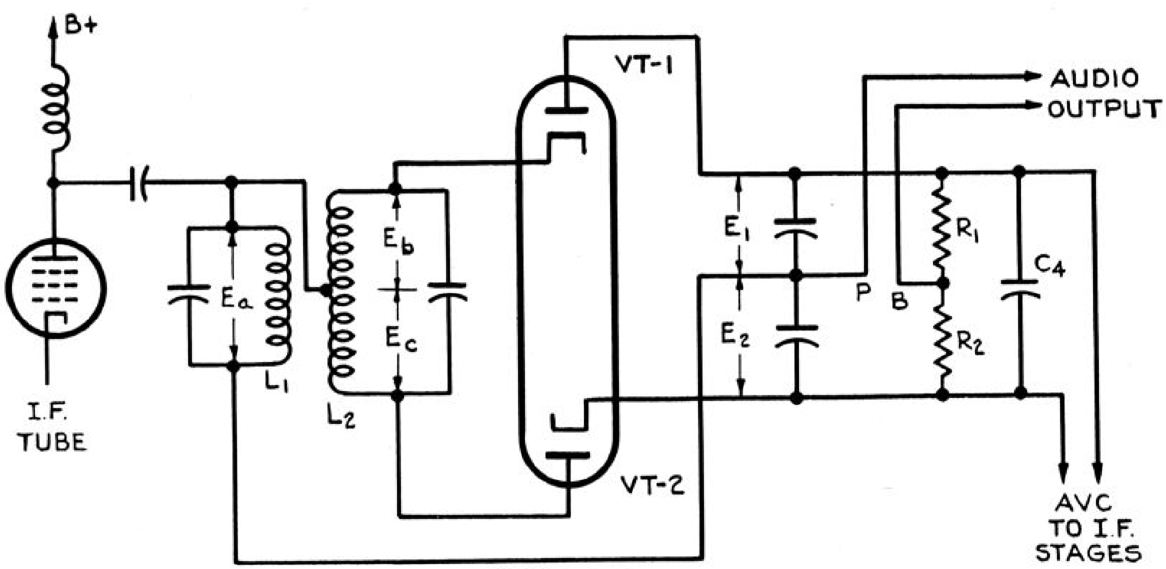


FIG. 2. *Ratio Detector.*

Now consider what happens when the r-f input frequency is different from the resonant frequency of the tuned circuit (as occurs in the normal frequency swing, or "modulation"). The secondary voltage leads the primary voltage by something less than 90° and the voltage addition is as shown in Figure 4. The r-f voltages E_1 and E_2 fed to the diodes are now different and the rectified outputs are also of different values. Thus, a d-c (or a-f) voltage, proportional to the frequency swing, is caused to appear at the audio output terminals.

An important disadvantage of this standard FM circuit is that while it is well-suited for FM detection, it is also sensitive to AM fluctuations in the input. This will be evident from a study of Figure 4 (i.e., the voltages E_a, E_b and E_c vary proportionately with AM modulation, but E_1 increases more than E_2, thus causing distortion in the audio output). In order to overcome the effects of AM modulation in receivers using the standard FM discriminator, it has been necessary to resort to the use of one or two limiter stages between the i-f stages and the discriminator.

The ratio detector, a simplified schematic of which is shown in Figure 2, is insensitive to AM modulation and hence requires no limiter stages. The reason for this may be understood by studying the two diagrams above. As will be noted, the input sections of both diagrams are alike. The r-f voltages fed to the diodes in the ratio detector are the same as those in the standard FM discriminator and they vary with frequency swing in exactly

While the sum of the diode output voltages E_1 and E_2 is thus held constant, the ratio of these voltages varies as the ratio of the input voltages. Thus, if audio connections are made at points "P" and "B" (i.e., in the cathode return circuit) an audio voltage proportional to the frequency swing is made avaiable. In this way, the ratio detector provides an FM detector equally as good as the standard discriminator and free from the latter's unwanted sensitivity to AM modulation.

Since the ratio detector does not respond to AM modulation, it is unnecessary to use limiter stages. This reduces the number of tubes required for the same performance. Moreover, since it

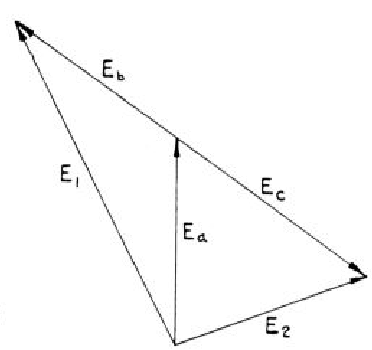


FIG. 4.

is not necessary to saturate a limiter, much weaker signals can

the same manner. However, in the ratio detector the diodes are

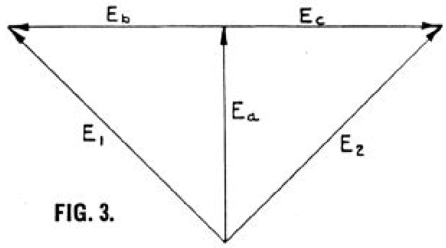


FIG. 3.

connected in series, so that the d-c (or a-f) voltages which they develop are additive (rather than being opposed as in the standard discriminator). Moreover, the sum of these voltages ($E_1 + E_2$) is prevented from varying at audio frequencies by the bypass condenser C-4.

be used and, therefore, a receiver using this circuit need not have the extremely high i-f gain which is necessary for satisfactory limiter action. This may make it possible to use fewer tubes in the i-f stages. (A laboratory model with only one i-f stage, and no limiters, has given very satisfactory performance even on weak signals.)

Another advantage of the ratio detector which, although a "by-product", is of some importance is that it provides a source of AVC voltage much more satisfactory than that available in the standard discriminator circuit. This voltage can be fed back to the amplifier stages thus maintaining the proper gain of the set for any incoming signal and thereby preventing overloading of the amplifier stages. Thus, interfering noises are less likely to cross-modulate the received signal. This effect also results in quieter and smoother reception.

4/25/10

John's Home Page

Slotted-Microstrip Antenna with Modified Ground Plane for Performance Parameters Enhancement

Conference Paper · December 2017

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Slotted-Microstrip Antenna with Modified Ground Plane for Performance Parameters Enhancement

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***Abstract*— This paper presents a compact slotted rectangular microstrip antenna with modified ground plane. Performance advancements with simple modifications of a reference antenna has been carried out in the entire work. The radiating patch and the ground surface has been loaded by two asymmetrical slots and two symmetrical slots respectively. This slight change in antenna shape makes the microstrip antenna more compact. In addition, the directivity, gain, and radiation efficiency have been enhanced significantly. The overall antenna size is 41.3 mm × 48.5 mm × 1.6 mm. The proposed antenna provides 19.8% of the compactness along with 2.9dB of gain enhancement, directivity boost of 2.5dB and radiation efficiency improvement of 25%, approximately. An acceptable relationship is observed between co and cross polarization from achieved patterns which imply the antenna structure as a qualified radiator in terms of polarization purity. A prototype is fabricated with proper characterization. The measured results have a good agreement with simulated results.**

***Index Terms*—Microstrip antenna, rectangular patch, symmetrical slots, asymmetrical slots, performance parameters.**

I. INTRODUCTION

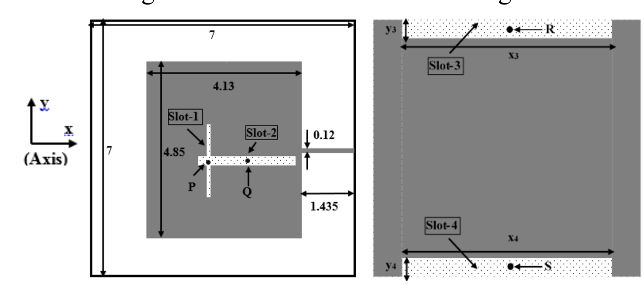
In the era of modern wireless communication, microstrip antennas are commonly used because of their several attractive features like low cost, low profile, light weight, ease of fabrication, etc. However, the microstrip antennas are having the laminations of narrow bandwidth and poor radiation characteristics inherently [1]-[2]. These antennas work efficiently near the resonance frequency due to the narrow bandwidth problem. Thus, precise determination of the resonant frequency of the antenna is mandatory. Patch dimension, effect of fringing field as well as the effective dielectric permittivity are the major issues which are required to take account on determining the resonance frequency of the antenna accurately [3].

Antenna gain enhancement is advantageous for increasing the transmission distance and for reducing the transmitter power consumption as well. Different techniques [4]-[12] have been employed to overcome the low gain problem of microstrip antennas. Multiple patches in an array have been used to enhance the antenna gain [4]. Slotted patch has removed the overall gain characteristics [5]. Laminated conductors have been implemented in order to increase the gain [6]. Adding parasitic patch as well as different types of feeding techniques have also been used to improve the gain [7]. A circular headed dumbbell shaped defected ground plane with peak realized gain of 9 to 9.5dBi and impedance bandwidth of 22% has been proposed in [8]. In [9], a high gain dual band resonance cavity antenna has been designed with orthogonal polarization using slotted patch over the ground plane. An antenna consisting of planer and vertical patches has been designed for gain improvement [10]. A wideband high gain antenna has been designed using the square patch on air substrate [11]. Antenna without external filtering circuit consists of both driven patch and stacked patch have been designed for gain enhancement [12].

In this communication, a high gain, compact and directive microstrip antenna has been designed with higher radiation efficiency. The performance parameters of the designed rectangular microstrip antenna are improved by two asymmetrical slots embedded on the radiating surface along with two symmetrical slots inserted the ground plane. The paper is summarized as follows: section II describes the antenna geometry. Section III describes the results with validation. Conclusion is given in section IV. Acknowledgment followed by references is then included at the ending of the paper.

II. ANTENNA GEOMETRY

The top-view and the bottom view of the proposed antenna are shown in Fig. 1(a) and Fig. 1(b), respectively. A rectangular patch having the dimensions of 41.3 mm × 48.5 mm has been designed by employing two stacked Rogers Duroid 5880 ($\varepsilon_{r1} = \varepsilon_{r2} = 2.2$ and $h_1 = h_2 = 0.762$mm) substrates sheets which have the dimensions of 70 mm × 70 mm. For excitation, a 50Ω microstrip feed line of dimensions 14.35 mm × 1.20 mm is used. For improving the performance parameters of the patch antenna, the radiating patch is loaded by slot-1 and slot-2 (having the same dimension) are inserted in the ground surface as illustrated in Fig. 1.



(a) (b)

(Center coordinates of the slots are indicated by P, Q, R and S. here, cm is used as unit in the complete geometry)
Fig. 1 Geometry of proposed antenna. (a) Top view and (b) Bottom View

Positions and dimensions of the slots on radiating patch and ground surface are optimized respectively to enhance the performance parameters of the antenna for the frequency range of 1.75 GHz to 2.50 GHz. The antenna geometry is designed using finite element method based HFSS (high-frequency structure

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simulator) software [13]. Dimensions of the inserted slots are mentioned in Table I. Here, the positions of the slots indicates the center location of the respective slots.

TABLE I
PARAMETERS OF INSERTED SLOTS

Slot Parameters	Value
Position of slot-1	P (x_1 = -3.0 mm, y_1 = -7.832 mm)
Position of slot-2	Q (x_2 = 6.8 mm, y_2 = -6.982 mm)
Position of slot-3	R (x_3 = 0 mm, y_3 = 32.5 mm)
Position of slot-4	S (x_4 = 0 mm, y_4 = -32.5 mm)
Dimensions of slot-1	20 mm × 1.0 mm
Dimensions of slot-2	26 mm × 2.5 mm
Dimensions of slot-3	55 mm × 5.0 mm
Dimensions of slot-4	55 mm × 5.0 mm

III. RESULTS AND VALIDATION

Fig. 2(a) and Fig. 2(b) illustrates the top view and bottom view of the fabricated antenna, respectively.


(a) (b)

Fig. 2 Snapshots of fabricated antenna (a) Top view and (b) Bottom view.

Fig. 3 depicts the S_{11} values comparison between the simulated and measured results of the slotted optimized antenna with the reference antenna where there is no slots in either of the patch or the ground plane. The Agilent N5230A network analyzer is used during the S_{11} parameters measurement of the fabricated prototype.

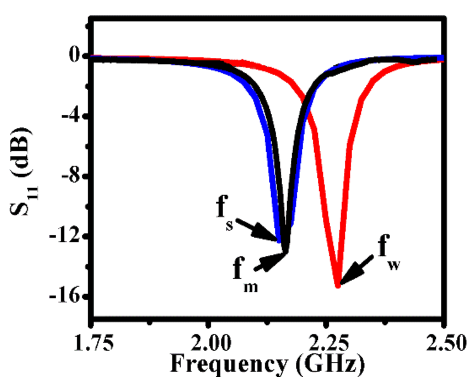


Fig. 3 S_{11} vs. Frequency comparison.

2.275 GHz of the simulated resonance frequency has been observed for the reference antenna (without slots). In case of the slotted optimized antenna, the simulated resonant frequency has been found as f_s = 2.15 GHz while measured resonance frequency of the fabricated prototype, f_m =2.155 GHz. Consequently, the measured and the simulated resonant frequency are observed as close enough.

The resonant frequency of the designed antenna has been reduced by 0.125 GHz by inserting the slots on both of the radiating patch and the ground plane. Slots on the antenna structure generally lengthens the surface current path which enhance the antenna length. As a result, the operating frequency of the designed antenna is dropped by 5.49% with respect to the reference antenna (no slots). This operation results in 19.8% (approximately) of the patch size reduction for an expected resonance frequency design. Thus, the optimized prototype displays a good compactness in size.

Fig. 4 depicts the contrast of simulated gain for reference antenna and the slotted optimized antenna. Numerically, 4.555dB of gain has been observed at the resonant frequency of the reference antenna. Slot insertion in the patch and ground surface has enhanced the gain 7.44 dB at the particular operating frequency (2.155 GHz) while simulation result shows 7.02 dB of gain at the operating frequency of 2.15 GHz. Thus, a significant betterment in case of gain has been achieved by employing the slots on both of the radiating patch and ground plane.

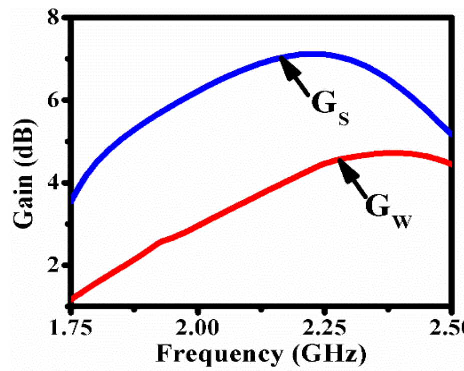


Fig. 4 Gain vs. Frequency comparison.

Friis formula of transmission is used to calculate the gain of the optimized slotted antenna as follows:

$$P_R = \frac{P_T G_T G_r \lambda^2}{(4\pi R)^2} \tag{1}$$

The experimental setup gives us P_T = Cable Loss = -8.5 dB, P_R = Received Power (Max. at 0^0) = -36.56 dB and R = distance between the testing antenna and the horn antenna = 200cm.

Now the wavelength, λ is computed as:

$$\lambda = \frac{c}{f} = 13.92cm \tag{2}$$

The intermediate factor used in (1) is computed as follows:

$$k = \left(\frac{\lambda}{4\pi R}\right)^2 = \left(\frac{13.92}{4\times 3.14\times 200}\right)^2 = -45dB \tag{3}$$

Now, finally the gain (dB) is computed as follows:

$$G_r = P_R - P_T - G_T - K = 7.44dB \tag{4}$$

The simulated directivity and the radiation efficiency comparison between reference antenna and slotted optimized antenna are presented in Fig. 5(a) and Fig. 5(b), respectively. The directivity of the patch antenna is observed as 5.06 dB whereas for optimized antenna it is observed as 7.5578 dB. Similarly, the

radiation efficiency of the reference antenna and the slotted optimized antenna is calculated as 70% and 95%, respectively.

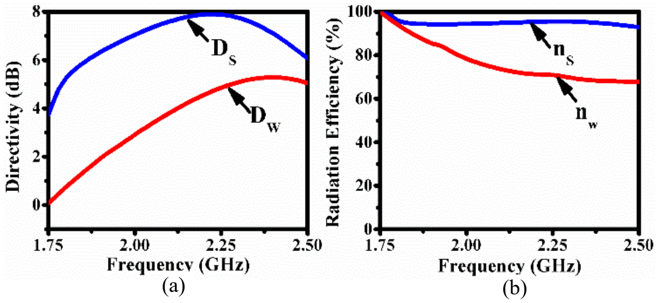
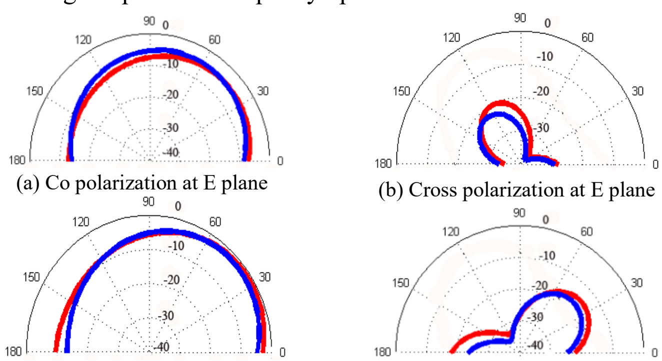


Fig. 5 Comparison of (a) Directivity and (b) Radiation Efficiency.

The achieved radiation patterns of the designed antenna are shown in Fig. 6. Fig. 6(a) and Fig. 6(b) illustrates co and cross polarization for E- plane respectively. A good agreement between simulated and measured patterns is observed. Likewise, Fig. 6(c) and Fig. 6(d) illustrates co and cross polarization for H-plane, respectively. Nearly 20 dB of difference between co and cross polarization is observed. Thus, the designed microstrip antenna having the polarization purity up to the mark.



(a) Co polarization at E plane

(b) Cross polarization at E plane

(c) Co polarization at H plane

(d) Cross polarization at H plane

Fig. 6 Achieved Radiation Patterns (Red lines indicate simulated patterns and Blue lines indicate measured patterns).

Hence, an excellent improvement is found in the slotted optimized antenna as compared to the reference antenna for different performance parameters such as operating frequency, directivity, gain, and radiation efficiency. In addition, the optimized antenna structure is more compact than the reference antenna. Furthermore, a good agreement has been found between the simulated and measured results. A slight deviation is noticed between the simulated and measured results. This error might take place due to staking of two same substrates during fabrication. Besides, effect of soldering in PCB board and connector has not taken under the consideration during the simulation work.

IV. Conclusions

A novel slotted-microstrip antenna has been demonstrated with a defected-ground plane to improve antenna performance such as compactness, gain, directivity and radiation efficiency. These parameters are improved in designed antenna compared to the reference antenna, which has no slots in both radiating patch and ground surface.

A prototype of the proposed antenna design has been fabricated with proper characterization for validation. An excellent convergence has been observed between the measured and the simulated results. A significant improvement in different performance parameters gain has been noticed by employing two slots on the radiating patch and another two slots in the ground surface. This encouraging amount of enhancement in four various performance parameters has made the proposed antenna an excellent alternative for enhanced radiation characteristics applications for wireless communications.

Acknowledgment

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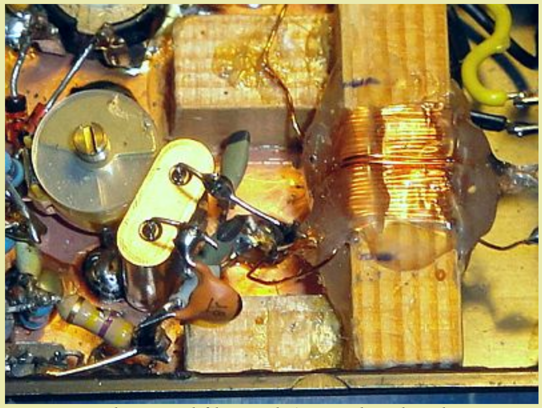
CRYSTAL FILTER FOR THE 30 METER QRSS BEACON RECEIVERS

(2011)

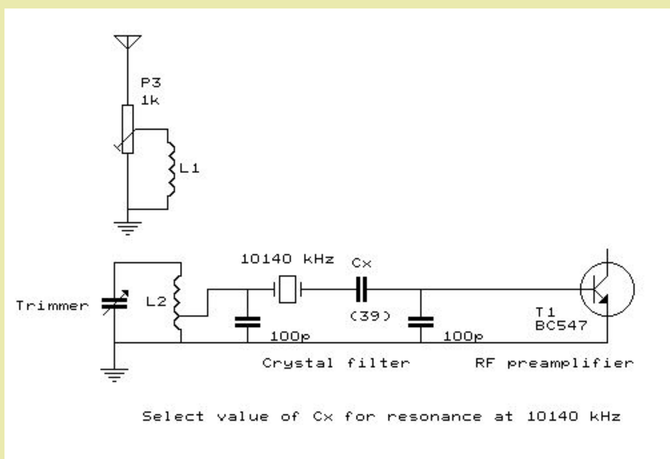
KLIK HIER VOOR DE NEDERLANDSE VERSIE



The crystal filter with 1 crystal is placed between the antenna coil and the RF preamplifier.

Crystal filter for the 30 meter QRSS beacon receivers

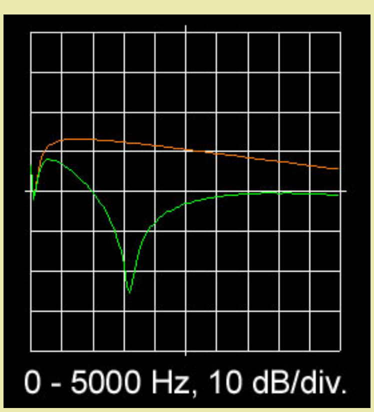
Two direct conversion receivers were made for the reception of QRSS beacon transmitters in the band 10140.0 kHz to 10140.1 kHz in de 30 meter amateurband. One with- and one without side band suppression with use of the phase method. During the evenings, these simple receivers had some problems with AM detection of strong broadcast stations and overloading due to strong radio stations near the reception frequency. Then the RF attenuator (potentiometer P3) has to be used, but that reduces the sensitivity of the receiver. By adding this simple crystal filter with only one crystal, the AM detection and overloading of the receiver do not occur anymore. Thanks to Johan, PA0TAB, who mounted a similar crystal filter in his receiver and who told me where the difficult obtainable crystals could be bought. At the local electronic parts shop for 3.65 Euro!

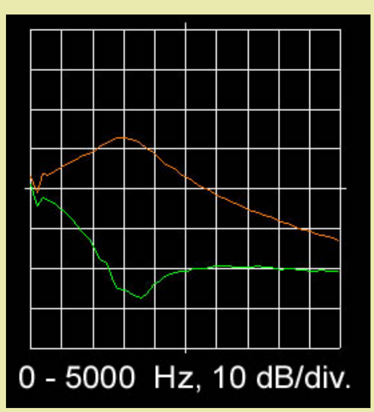


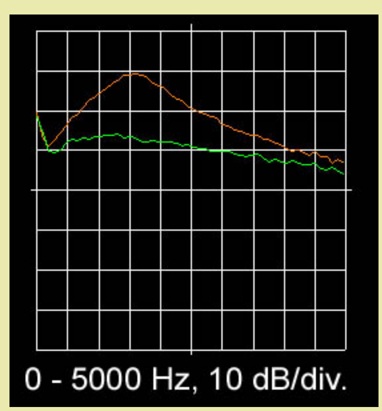
The diagram of the crystal filter, that is inserted between the antenna coil and the RF preamplifier.

The crystal filter

The capacitor of 1 nF between L2 and T1 has been replaced by a simple crystal filter with 1 crystal of 10140 kHz, a series capacitor Cx and two capacitors of 100 pF to ground. The value of the capacitor Cx is chosen for resonance at 10140 kHz. For my crystal, 33 pF was too small (resonance frequency too high) and 47 pF too large (resonance peak too low). As I did not have a capacitor of 39 pF anymore, a capacitor of 18 pF and one of 22 pF were connected in parallel for a Cx value of 40 pF.



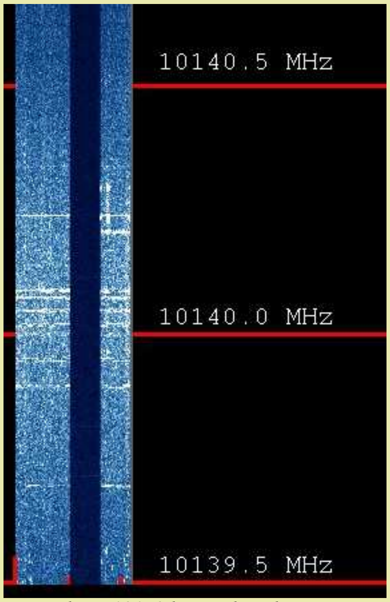




Receiver with side band suppression without crystal filter | *Receiver with side band suppression with crystal filter* | *Receiver without side band suppression with crystal filter*

Frequency characteristic (orange line) and side band suppression (difference between orange and green line).
The reception frequency of 10140 kHz lies at the audio frequency of 1550 Hz in the graph.

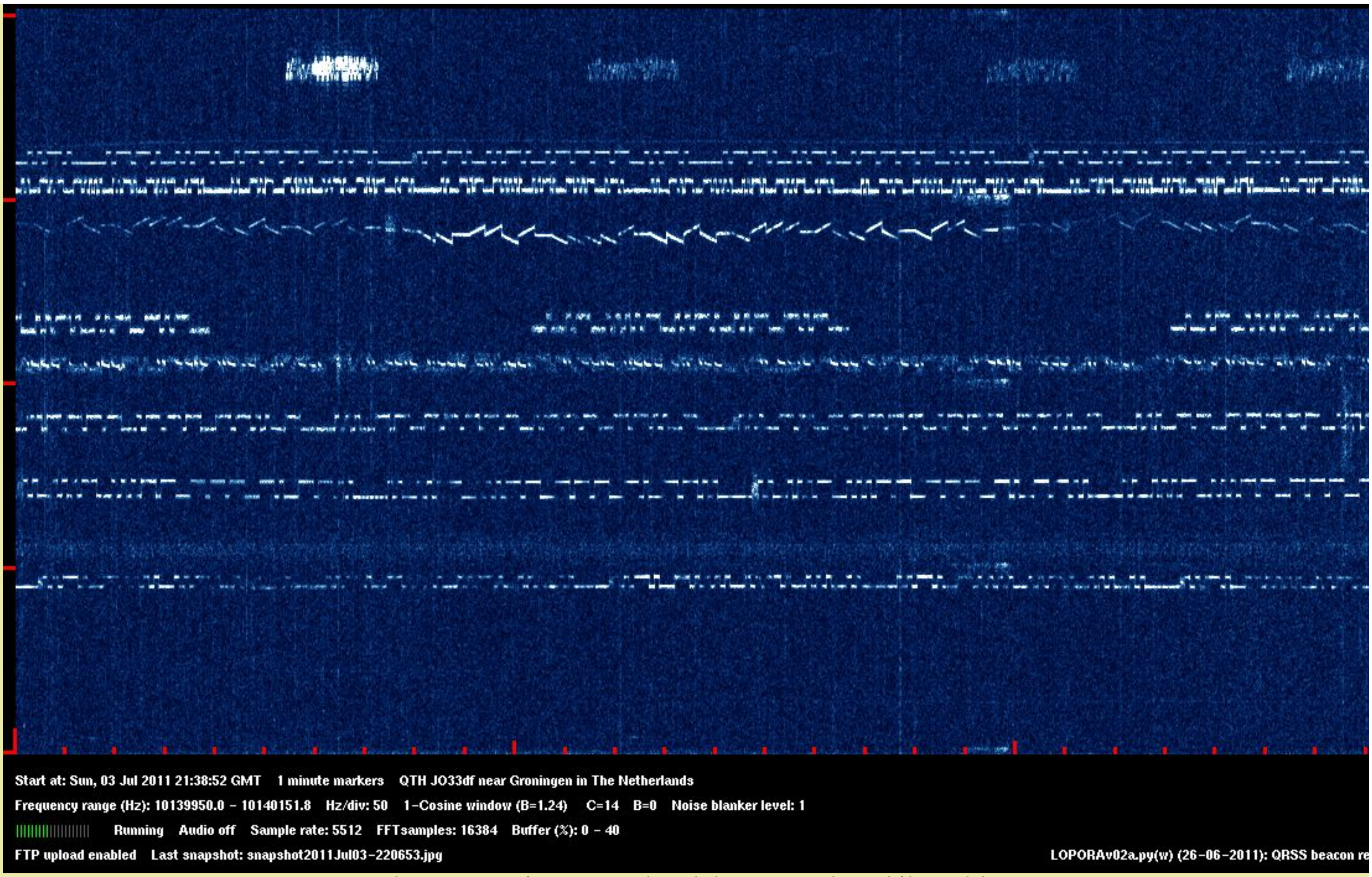
The improvement
The crystal filter is approximately 800 Hz wide. Wide enough to receive also WSPR signals between 10140.1 kHz and 10140.3 kHz. Strong signals outside the bandwidth of this very simple crystal filter are upto 30 dB attenuated! The AM detection of strong broadcast transmitters and also overloading of strong signals near the reception frequency are completely gone. The RF attenuator (the potentiometer P3 of 1k ohm at the input) does not have to be used anymore.
Also the side band suppression is better. Even the simple receiver without side band suppression, does already have a suppression of 18 dB of the unwanted side band due to the simple crystal filter and with this filter, it will perform nearly as good as much more expensive receivers.



The spectrum. The noise peaks at 10140 kHz. When disconnecting the antenna, you can see a dark strip in the spectrum. So the own noise of the receiver is really low.

Picture of the spectrum
The sensitivity of the receiver is excellent. You can see that on the picture here above of the spectrum. When the antenna is disconnected, you can see a dark strip in the spectrum, as the noise almost disappears. The noise of the receiver is almost negligible. In fact, the sensitivity is too good. Some RF attenuation is adviceable to increase the dynamic range. On the picture, you can also see that the filter peaks on 10140 kHz. At this frequency, the noise is maximal. With use of such a spectrum picture, you can easily determine the correct value of Cx.

Omnidirectional reception antenna.



And just a picture of reception results with the receiver with crytal filter and the QRSS beacon reception program LOPORA (LOw POwer RAdio), written in the programming languate Python.

QRSS links:
Simple QRSS receiver without side band suppression
Simple QRSS receiver with side band suppression according to the phase method
Grabber for reception results of QRSS beacons

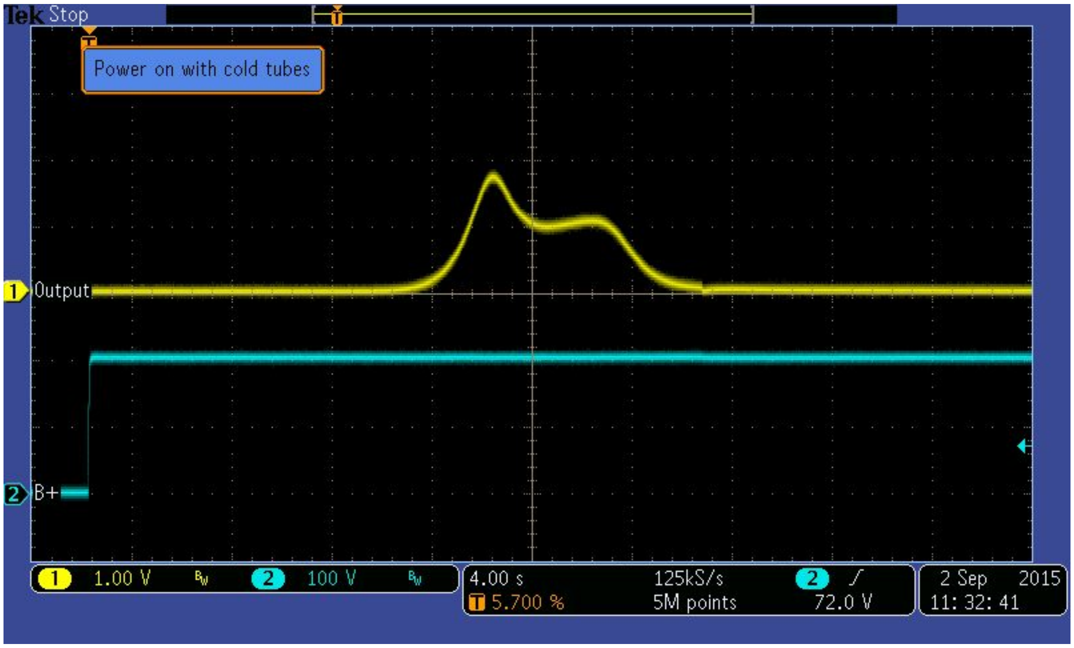
BACK TO INDEX PA2OHH

[DIY Audio Home](http://www.pmillett.com/)

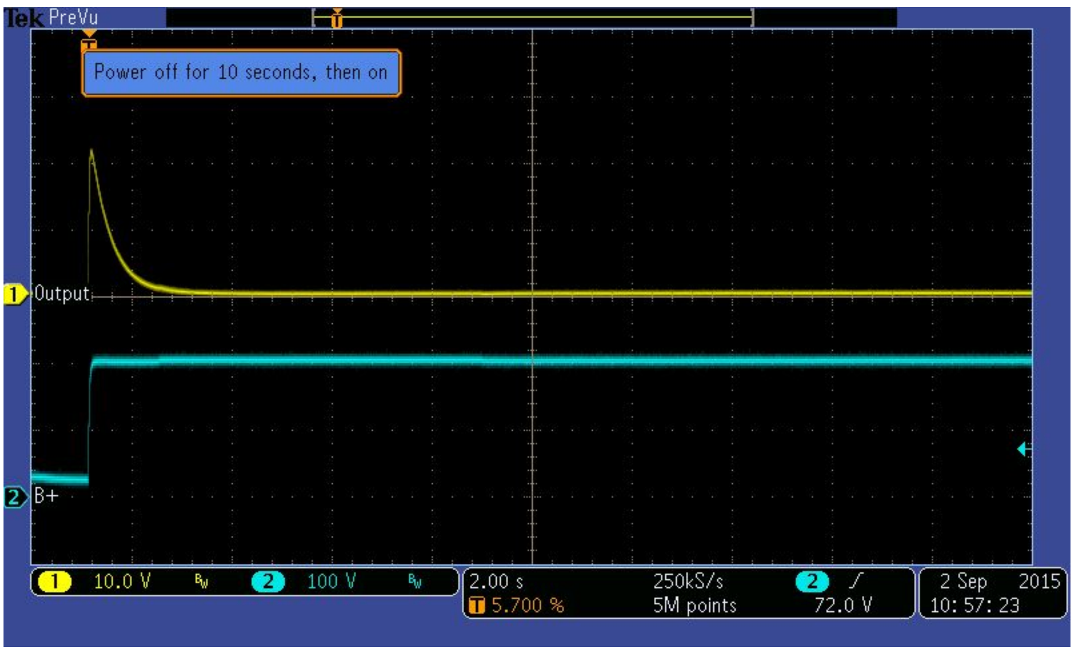
Muting relay PCB

With cap-coupled preamps and single-ended power amps in particular, there is often a "thump" heard in the speakers when powering up. I switch the power to my entire system together, and when I added a couple of subwoofers that have solid-state amps (that turn on instantly), that "thump" was pretty annoying.

I've been questioned as to the need of a muting circuit on a tube preamp. The assertion was that the tubes warm up slowly enough that there should be no issue. I beg to differ...

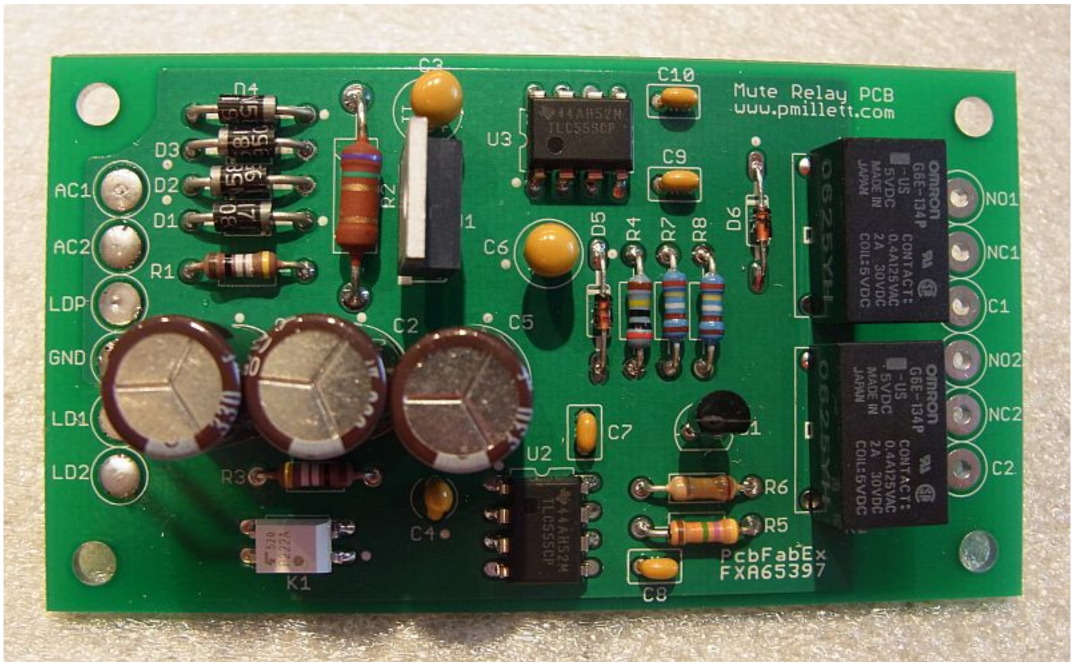


This is a scope shot of the output of "el escorpion" (before the muting circuit) showing power-up with cold tubes. The output goes through a ~1V "bump" as the tubes start conducting. This is a low-frequency thump. If you are using an amplifier and speakers with poor low frequency response, it might not cause you too much of a problem. But even with normal amps you will see the woofer cones do a little dance. And if you have a subwoofer connected, it will sound like somebody just dropped a bag of sand on your roof.

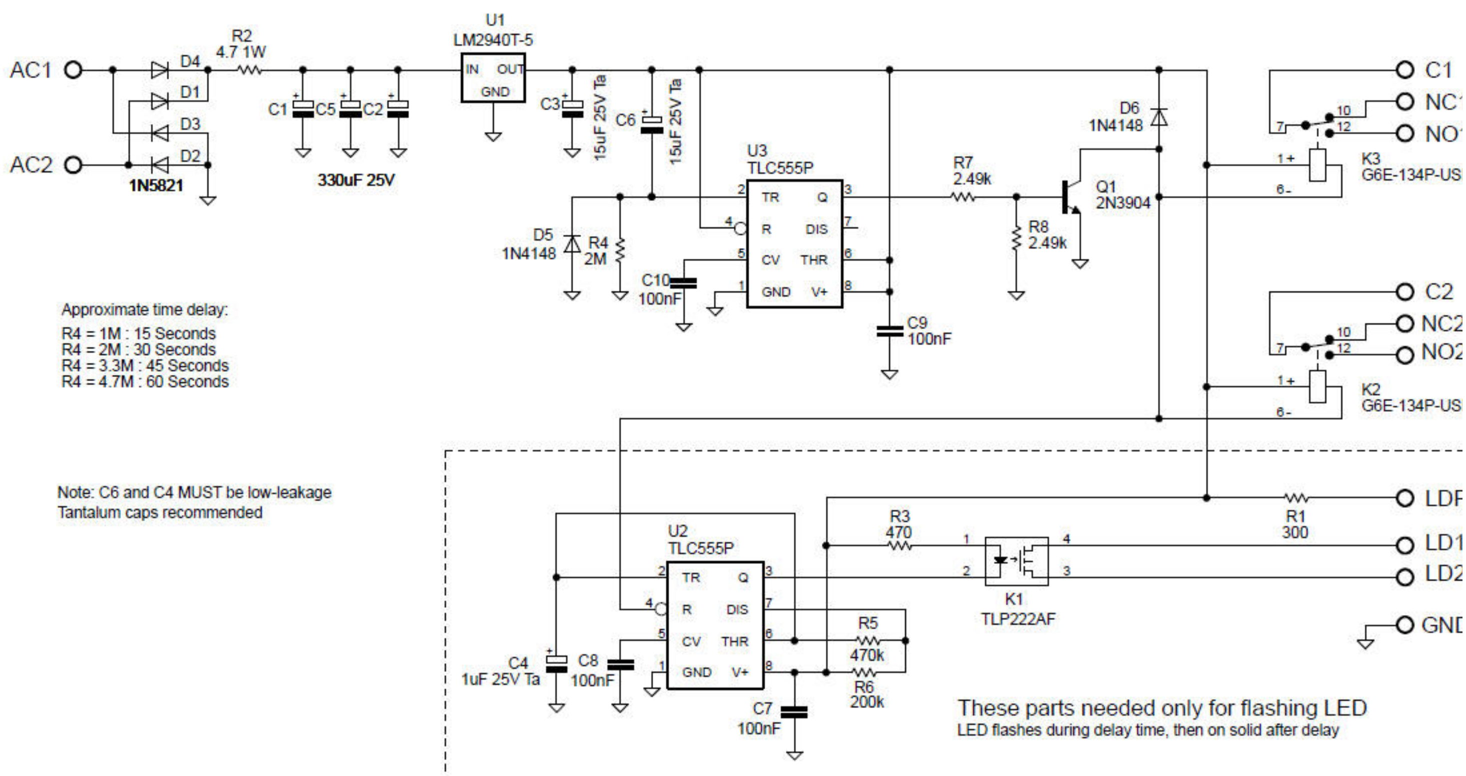


This scope shot hows a bigger danger: what happens if you power off, then back on, if the tubes are still warm. That is a 20V spike on the output. That's enough to pop your woofers. Even if you are careful to never do this, there is always the possibility that the mains voltage may drop out for a short period (it happens all the time here during thunderstorms).

So, when I built "el escorpion", a preamp-in-a-cigar-box, I decided to build a small circuit that could be used to mute the outputs for a period of time while the tubes warmed up.



Here's the schematic (or [download it in .PDF format)](#):



The input can be either AC or DC - typically, the heater supply of 6.3V or 12V is used. In "el escorpion" I was running everything from a 12V DC supply, so I just connected that to the input. If you want, if using DC, you can eliminate the diodes (replacing D4 and D2 with jumper wires)and all but one input capacitor if you want. A 5V LDO regulator is used to generate a 5V supply for the rest of the circuit.

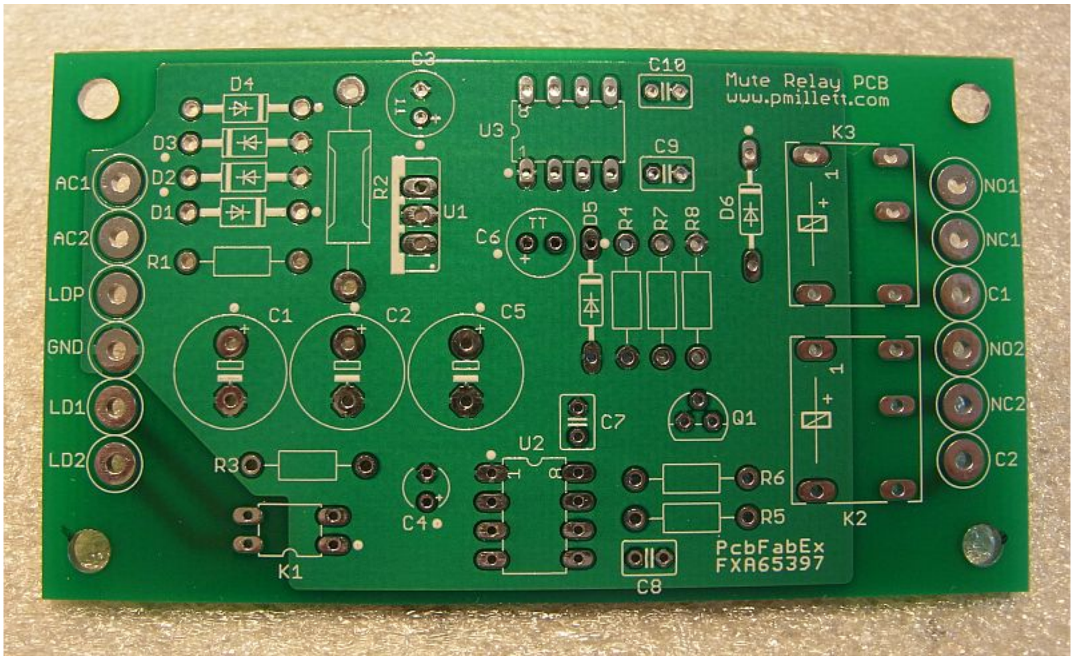
The board has two sections: the upper one on the schematic is used to generate the delay. The lower one is used to make a power LED or pilot lamp flash during the warm-up time. If you don't want this feature you can leave out all the parts inside the dotted box on the schematic. I like the feature, sine it lets you see that the power is on but output is muted. After the mute period expires, the LED is lit solid.

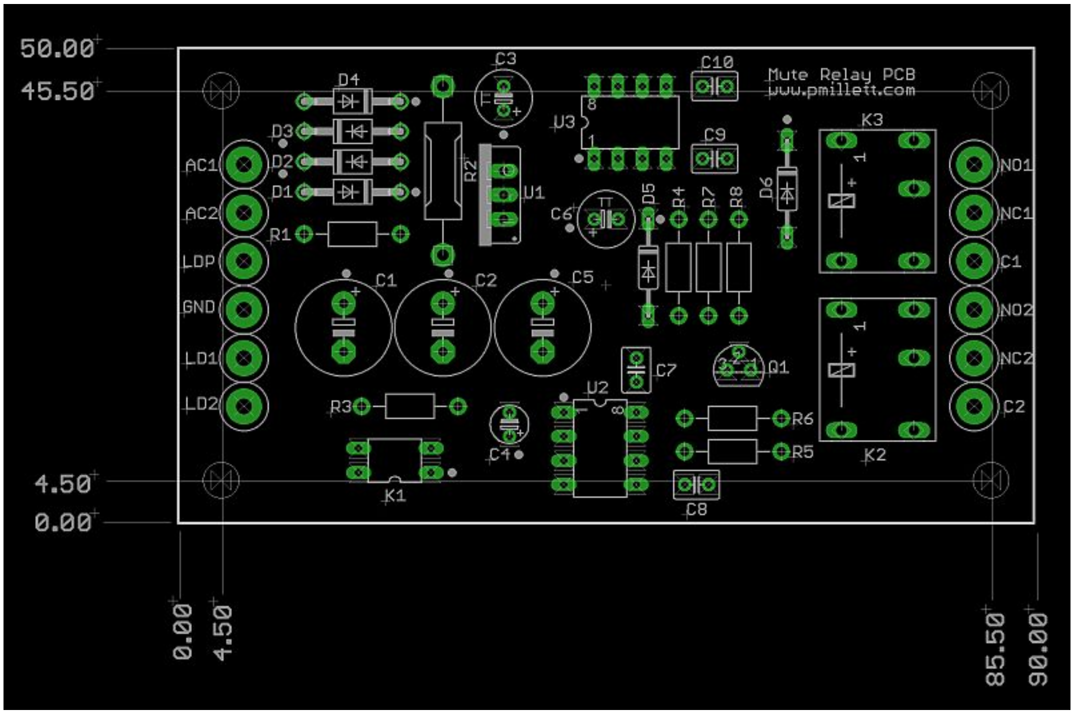
The delay and flashing is implemented using 555 timer ICs (TLC555 form TI). The delay time as shown is about 30 seconds. You can make C6 or R4 bigger to increase the time, or smaller to decrease it.

I used two SPDT relays, so I could get a contact rating high enough for a power amp. These relays are rated for 3A, which is OK for power amps up to 50 watts or so. If you need something bigger, you can use the output to switch the coil of a bigger relay. Note that the contacts are rated for up to 250VAC only, and not rated for high voltage DC - ***do not use this to directly switch a high-voltage B+ supply!***

The LED or pilot light output is switched by a small MOSFET solid-state relay. This can switch AC or DC at low current. If you use an LED, you can connect the anode to the LDP terminal and cathode to LD1, and jumper LD2 to GND. This will use the regulated 5V and resistor R1 to drive the LED. If you are using some other form of light (an external lamp or LED with resistor), just use the LD1 and LD2 terminals as a switch and wire it in series with the lamp.

The circuit is simple enough that you can build it on perfboard. Since I like designing PCBs, of course, I made a PCB for this. The PCB is 50mm x 90mm:





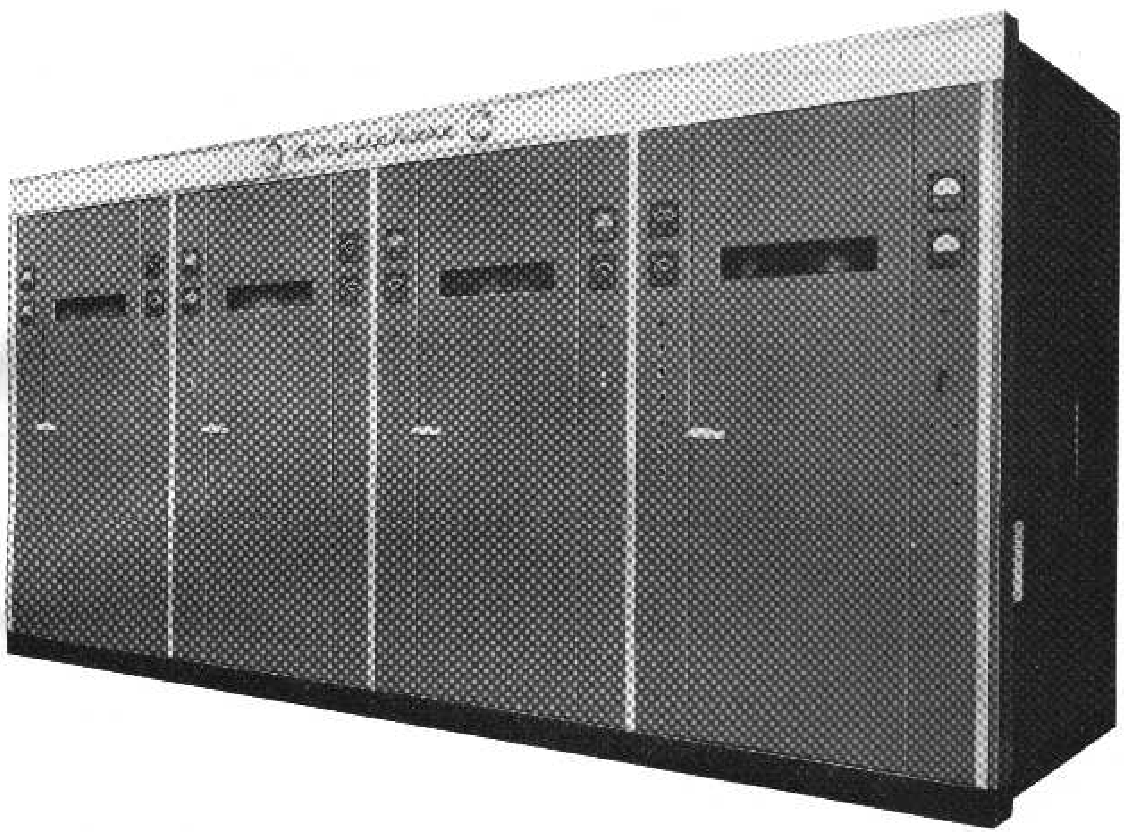
The parts can all be purchased from Digi-Key. Here is a parts list (Bill of Materials) in .XLS or .PDF form.

I will sell the PCBs in my eBay store.

Principles of Operation of the Ampliphase Transmitter

This article was published by RCA in Broadcast News, Vol. No. 104, June, 1959.

It explains the principles of RCA's first Ampliphase Transmitter, the BTA-50G
50 kW AM Broadcast Transmitter.



This is the 50,000 watt "Ampliphase" Transmitter now in operation at 12 major stations.

PRINCIPLES OF OPERATION OF THE *Ampliphase* TRANSMITTER

A Combination of Phase Modulation and Regulation of RF Drive to Produce 50 KW Output

by A. M. MILLER and J. NOVIK, *Broadcast and Television Equipment Division*

The *Ampliphase* system of modulation has been commonly described as a "Phase to Amplitude" process. It is that plus

Basic Operation

The general block diagram of the transmitter (see Fig. 1)

application of some additional circuit techniques. Otherwise, performance in accordance with the rigid specifications could not be achieved. Hence, performance records of the *Ampliphase* 50-kw Transmitter at 12 major stations point to three very specific benefits: economy of operation, increase in program coverage, and improved sound.

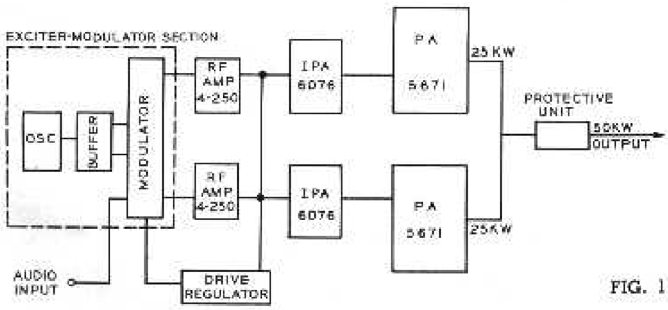


FIG. 1

shows the layout and various designations of the blocks; this should be studied carefully. If the modulator and drive regulator blocks are omitted, the remaining stages are shown in Fig. 2.

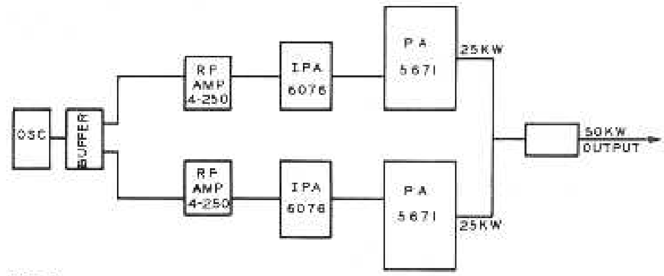


FIG. 2

An oscillator and buffer stage is followed by three broadband amplifier stages, with three identical ones running in parallel, forming a second rf amplifier chain or channel. Then note that the channel outputs are connected to make the equivalent of two 25-kw transmitters operated in parallel to produce 50-kw of output power.

Exciter Modulator Section

Returning to Fig. 1, the complete block diagram, take from it the simplified exciter-modulator section, and unfold it in the form of another block diagram (see Fig. 3) and add to it, for the moment, a small combining network at its output, and consider it operable as a unit.

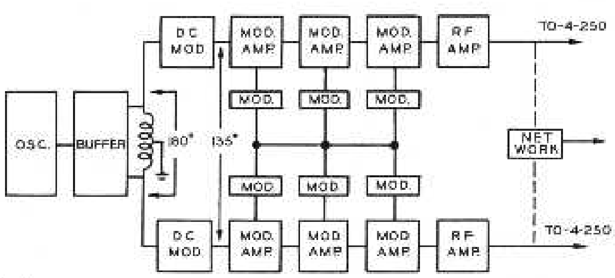


FIG. 3

Here a single crystal oscillator followed by a buffer amplifier stage, with the rf output divided by center-tapping the tank circuit to ground is shown. Then by connecting both ends of the coil to independent, identical rf channels, it becomes obvious that these two signals would be 180 degrees out of phase; furthermore, if the signals are recombined, zero output would result. Thus, there is a need for another stage in the respective signal paths, to provide appropriate phase shift that will prevent cancellation of the signals, and to provide an output of some desired value. This is accomplished by the stages designated as "dc modulators." They have been given a phase shift to 135 degrees. Following the "dc modulators" in each channel are three stages marked "Modulated Amplifiers," and a fourth, marked "rf Amplifier." The three modulated amplifiers in each channel are identical in circuit and function.

Phase Relationships

The simplest approach to understanding the system is through vector analysis. Figure 4 shows vector "OC" representing current, and "OA" and "OB" representing the phase relationship of channels "A" and "B", thus the output is zero.

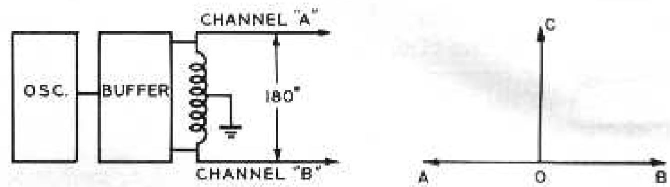


FIG. 4

However, if the phase difference between the two channels is shifted to 135 degrees (see Fig. 5), a certain amount of output current will result, as indicated by vector "OC_1".

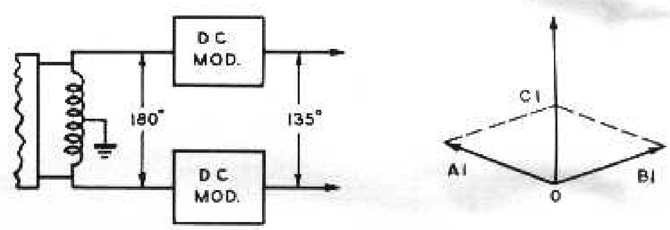


FIG. 5

Continued shifting of the phase on to a 90 degree difference, as shown in Fig. 6, causes the output current to double, as represented by vector "OC_2".

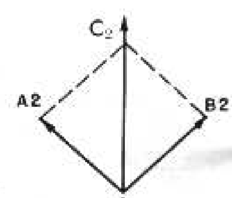
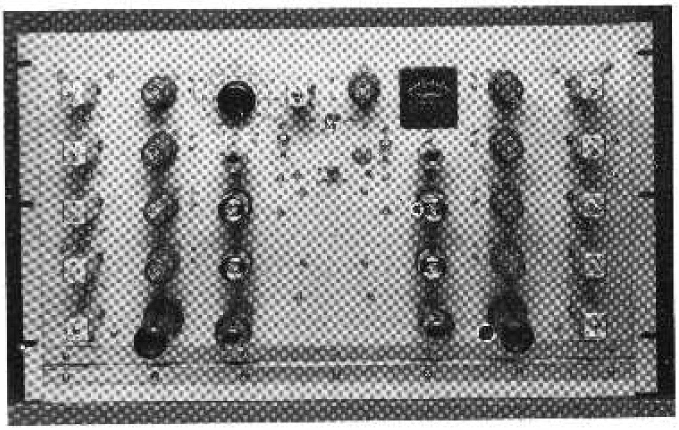


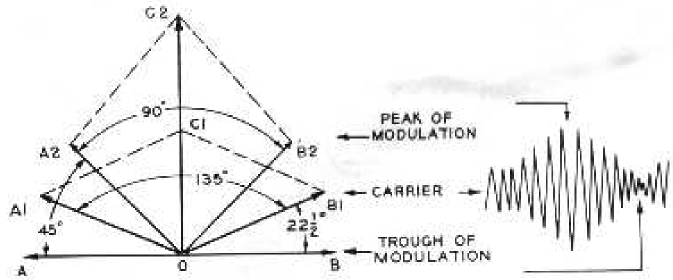
FIG. 6

A combination of the three vector drawings (Figs. 4, 5, and 6) provides a composite vector (see Fig. 7).



This is the exciter modulator unit, each channels separate components are mounted on the same chassis. In the Ampliphase transmitter two of these exciter-modulator units are provided, and duplication of these low power stages increases transmitter reliability.

FIG. 7



Here a 180-degree phase difference produces zero output, and this corresponds to the trough of modulation. A shift to 135 degrees would provide a given current that can represent the carrier. Then, on to 90 degrees, note the load current is double with respect to 135 degrees. Doubling the current or increasing the power by four times produces a condition corresponding

to the peak of modulation. If a phase difference of 135 degrees is designated as carrier, and an excursion in each carrier of ±22.5 degrees is utilized, then conditions of no output can be produced (corresponding to trough of modulation), and through a point where the load current will double (corresponding to 100 percent modulation).

Phase Shifting Circuitry

The block diagram of the exciter (see Fig. 3) shows that the phase shifting requirements can be readily accomplished. The methods used can best be explained by an examination of the circuitry in each contributing stage.

Figure 8 shows a simplified circuit diagram of dc modulator stage.

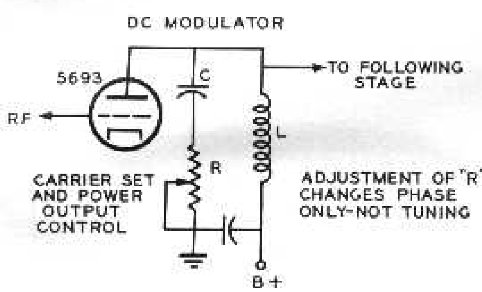
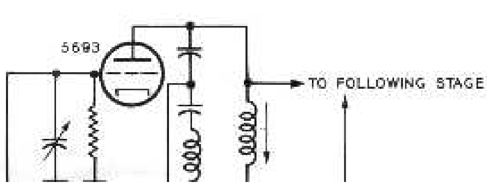


FIG. 8

It is simply an rf amplifier with a variable resistor in a low "Q" plate tank circuit, and the phase can be controlled by adjustment of this resistor. The values of "L" and "C" are selected so that a change in "R" does not change impedance, only phase.

Figure 9 shows how the two dc modulators are utilized together, with variable resistors on a common shaft to control the carrier.



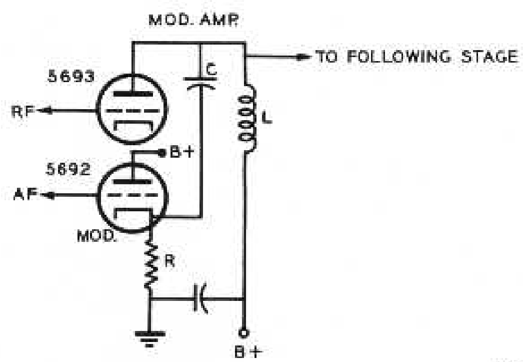


FIG. 10

Figure 11 shows how the two modulated amplifiers are connected in their respective channels.

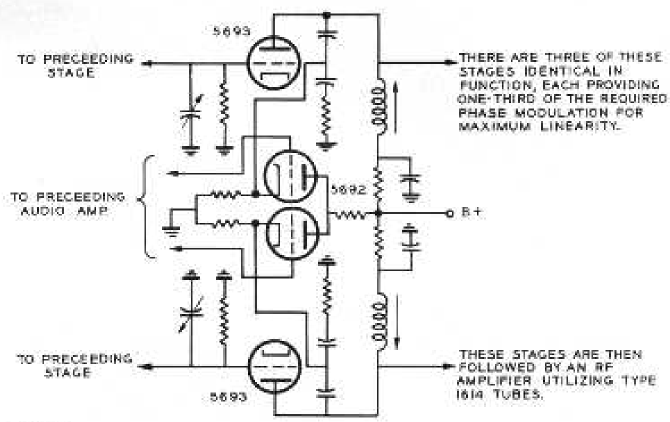


FIG. 11

There are three modulated amplifiers in each channel, making a cascade modulator. This circuit technique makes it possible to produce a phase modulated signal by the simple plate resistance method with negligible distortion. As mentioned earlier, a phase change of ±22.5 degrees is desired. A phase excursion of this magnitude in a single stage would result in distortion beyond specifications. By doing it in the cascade, the phase excursion is less than ±8 degrees per stage and

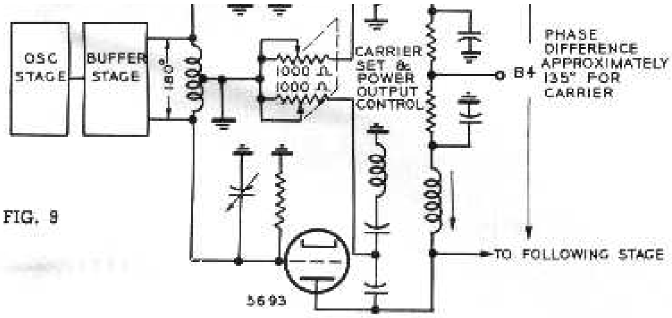


FIG. 9

Modulated Stages

Following the dc modulators, there are three identical stages in each channel, designated as "Modulated Amplifiers." Each stage is almost identical to the dc modulator, except that instead of a variable resistor in each plate tank circuit, a triode tube is substituted which serves as a variable resistor capable of variations at audio frequencies (see Fig. 10). As an audio signal is applied to the grid of the modulator tube, a phase modulated signal is produced in the tank circuit.

after three stages produce a resultant ±22.5 degrees, with low distortion. Following the modulated amplifiers a conventional amplifier stage is used to provide isolation and drive to the first intermediate power amplifier. In the BTA-50G the output of each channel from the exciter modulator is fed to a series of three conventional broadband amplifiers, providing the necessary power gain to produce the desired 25-kw in each channel. These are combined for the 50-kw output.

Drive Regulation

To achieve a high degree of efficiency during modulation, and a high peak modulation capability with minimum carrier shift and distortion, a "Drive Regulator" is added. This technique contributes to a "Phase to Amplitude" system of modulation the element that completes the *Ampliphase* concept.

It produces a practical modulation process for high power AM transmitters that is both reliable and economical. The "Drive Regulator's" location with respect to the system is shown in Fig. 1. The simplified diagram of Fig. 12 shows how the output of the "Drive Regulator" is applied to the grids of the IPA stages.

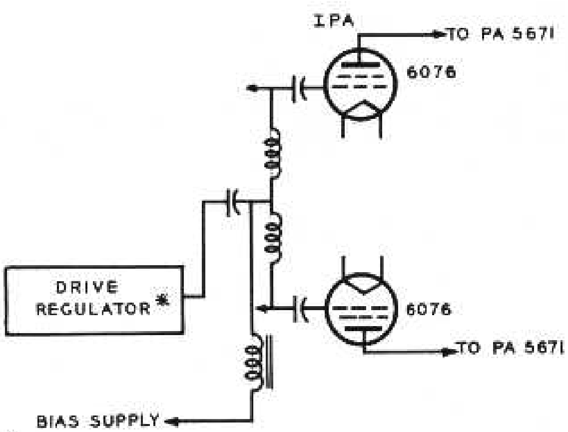


FIG. 12

The drive regulator is an audio amplifier with a cathode follower type output, utilized as a "dynamic bias control," functioning synchronously with the modulation process. It provides a variation of drive to the final PA stages, controlling the output currents in direct relationship to the load requirements at the various percentages of modulation. Consequently, the efficiency at average modulation is essentially the same as at carrier.

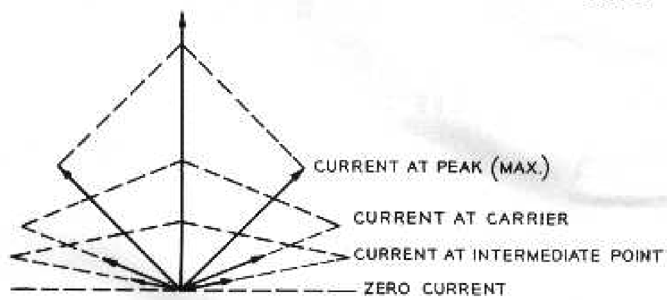
Consider for a moment, operation without drive regulation. At the peak of modulation (100 percent), each output tube must supply two times its carrier load current, while at the trough of modulation (100 percent), no load current is required. Therefore, the output tubes see an apparent impedance varying over a wide range during the modulation cycle. Under these conditions the rf plate voltage on the output tube would obviously not be constant. In result, the modulation peaks would not raise to the required value, and conversely, at the trough of modulation, the tubes would be over-driven as related to the output current requirement.

Vector Relationships

Again, a family of vectors can be used to illustrate and com-

efficiency is acquired as the drive is controlled to supply current only as needed. The vector presentation (see Fig. 14) depicts the variable current as well as the phase relationship.

FIG. 14



Linearity Control

Figure 15 shows a simplified diagram of the drive regulator stage. Note that it utilizes two intermediate stages in parallel, one with adjustable bias and adjustable input to allow increased output on audio peaks; and it is called a linearity stage. By the

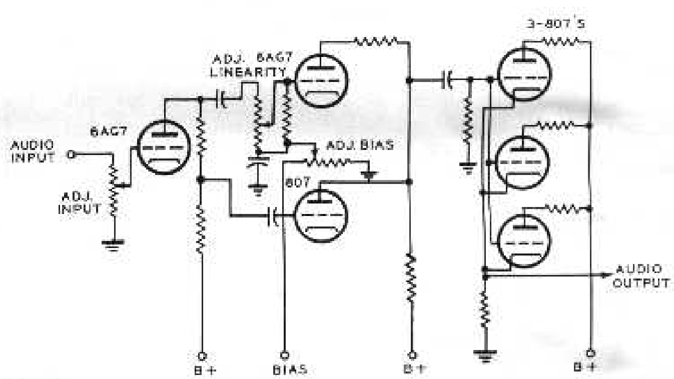


FIG. 15

adjustment on this stage, compensation for normal tube characteristic non-linearity can be achieved (see Fig. 16A). A slight

pare the current and phase relationships, depicting what happens to the vectors when drive regulation is applied. Not only is the phase location of the respective vectors controlled but their length (magnitude) as well.

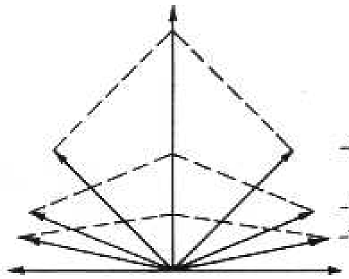


FIG. 13

In a constant current vector presentation as shown in Fig. 13, again it is obvious that from the trough of modulation (100 percent) to the peak of modulation, or the power change from zero to four times carrier, the rf plate voltage would swing from a very low to a very high value. However, if the current is varied along with phase, not only is a proper relationship of current and voltage to load achieved, but an improvement in increase on peaks makes up for this discrepancy, and provides a resultant as though the tube curve was straight, as indicated by the dotted line (Fig. 16B).

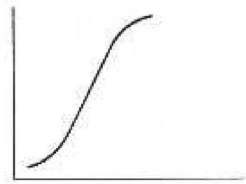


FIG. 16A

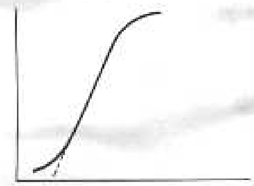


FIG 16B

Feedback

A small amount of overall feedback is used in the system. This is accomplished by sampling the rf output at the reflectometer in the transmission line. The reflectometer employs a balanced germanium diode detector, and is compensated to prevent regeneration across the audio spectrum. One further precaution is taken in that an adjustable diode limiter circuit is built into the phase modulator so that if high peaks or transients should occur, the phase shift will never exceed optimum or cross over on the peaks of modulation to change the feedback polarity.

7/26/00

Return to John's Ampliphase Page

John's Home Page

DIY Audio Home

The "Starving Student" hybrid headphone amplifier

The "Starving Student" hybrid headphone amp is the result of my effort to design the simplest, cheapest tube hybrid headphone amplifier possible. Think "Millet hybrid" on a starving student budget.

For more info, examples, etc. please check out the Starving Student amp thread on Head-Fi.

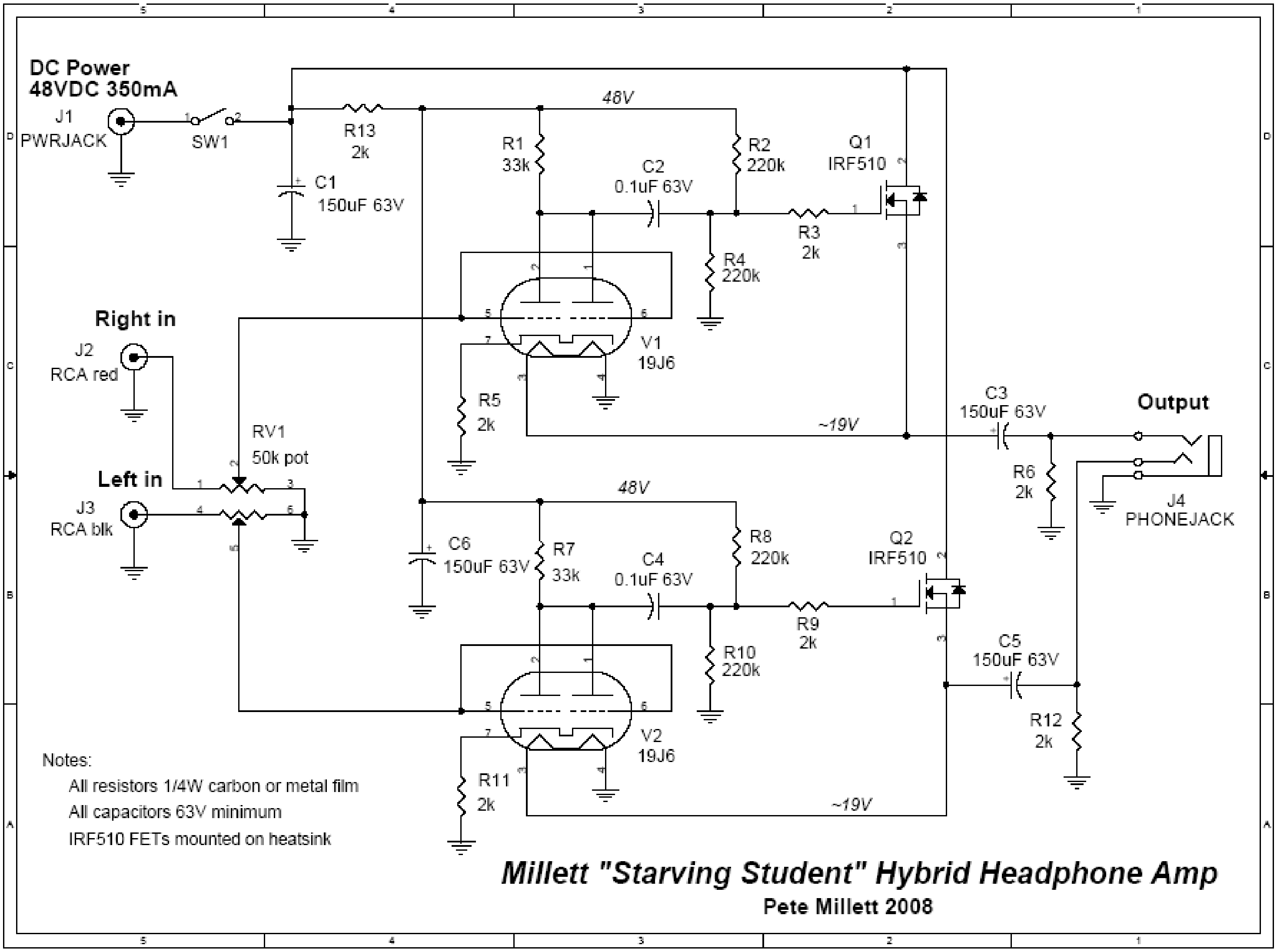
Also, visit DIYForums for construction info and Beezar.com to buy parts and boards!

Also, check out the Starving Student photo gallery.

The result was surprisingly good!

The amplifier uses a pair of 19J6 tubes as a voltage amplifier stage - they're cheap, have high Gm, and the heater makes a perfect resistive load for a MOSFET source follower.

Say that again?



.

Yes, the tube heater is used as a resistive load for a power MOSFET source follower. The output is then capactively coupled from there. the 19J6 heater is rated at 18.9V and 150mA. 150mA is a nice healthy current to have running in the output stage - it will drive 32 ohm headphones with ease.

In case you're wondering, yes, it's OK to put audio on the tube heaters. Think about it - normally they run on 19V RMS AC. In this case they're running on 19V DC, with a little bit of audio superimposed (rarely more than 1V or so). There could (theoretically) be a little coupling from the filament to the cathode - the cathode resistor is un-bypassed - but it would be negative feedback, and the capacitance from heater to cathode is so low compared to the cathode resistor it would probably only be measurable at RF frequencies.

Here's a PDF file of the schematic.

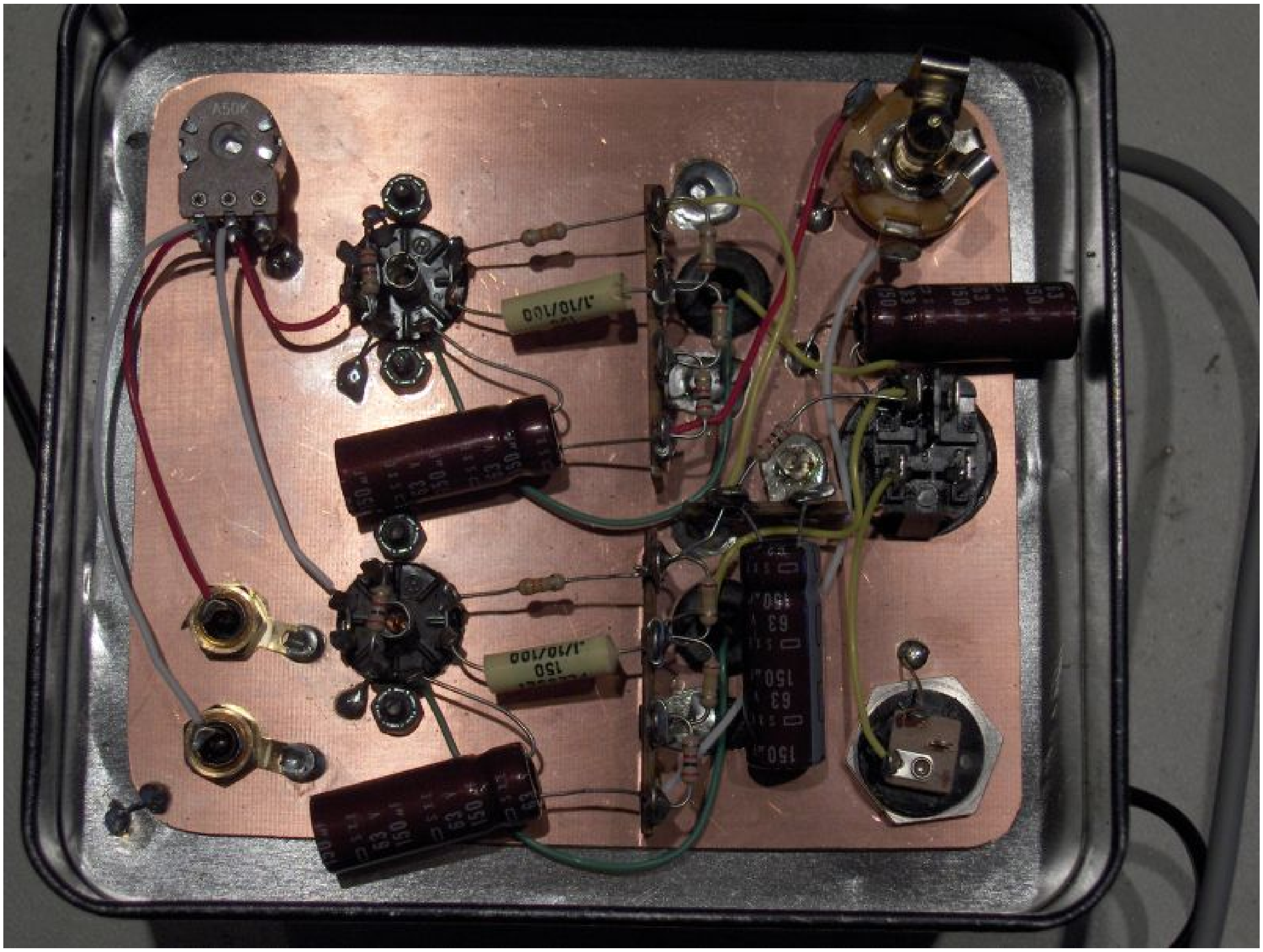
With 19V across the heater, a 48V power supply is about ideal. 48V also provides enough voltage to get decent linearity from two paralleled 19J6 triode sections, using a simple resistive plate load. And guess what - 48V power supplies are dirt cheap! I used a 48V wall supply designed to power Ciso IP phones and POE power injectors. They go for around $7.00 on eBay, and are very common.

At power-up the supply struggles a bit to start up into the cold tube heaters, which draw a lot more current when cold. The power supply current limit cycles, but eventually dumps enough energy into the heaters to get them warm, and starts up.

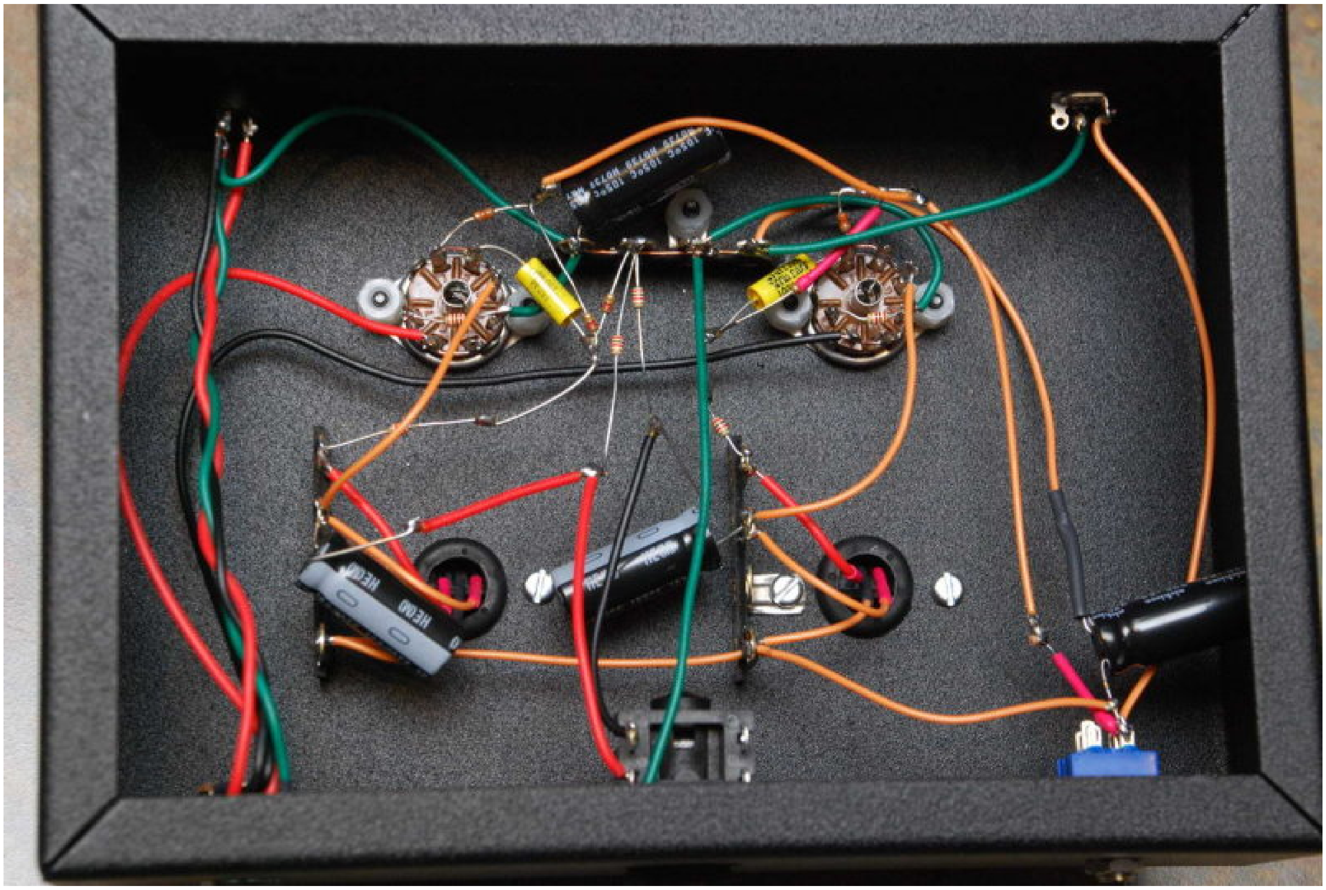
Parts were selected so that there are as few items in the bill of materials as possible. No fancy parts, just normal, good quality R's and C's. The total cost of construction of this amp came in at $35.80 - to put it in "starving student" terms, about two delivery pizzas and drinks. This included everything except wire, solder, and the enclosure. In my case, the enclosure used was a recycled box that a wallet came in.

Here is the bill of materials in PDF or .XLS spreadsheet form.

This amp is simple enough for even a first-timer to construct point-to-point, with no PCB. You could build it in a normal chassis, but I chose to recycle a metal box I had sitting around that packaged a wallet I bought.



I used a piece of blank PCB material inside the box, partly to stiffen it (it's pretty thin metal), and partly to use as a ground plane. You can also wire this point-to-point without a ground plane. Nate Maher built a version this way:

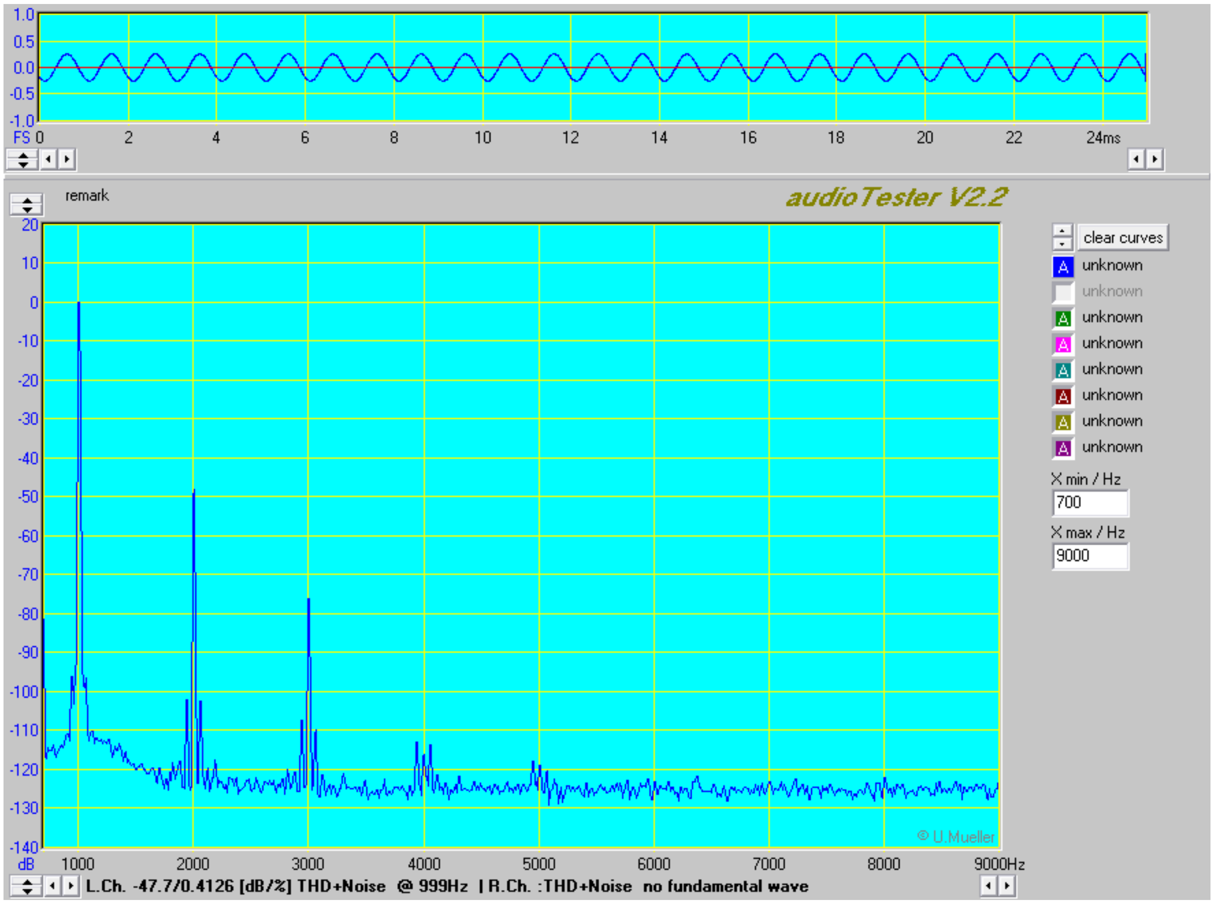


Here's an outside look at Nate's amp:

Very nice...

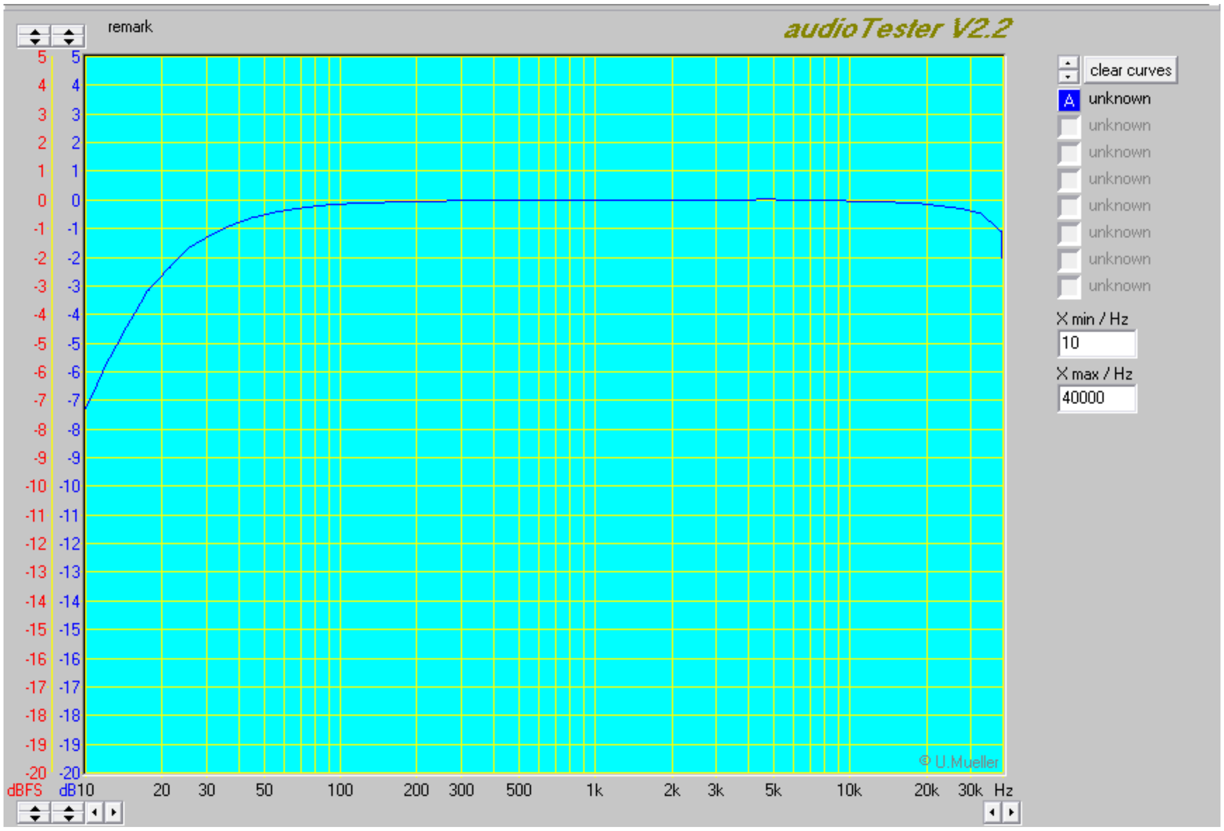
This is a fairly tubey sounding amplifier, similar in character to the original hybrid tube headphone amp design I published in audioXpress waaay back in 2002.

At 1V RMS out, THD is around 0.39%. Note that this figure is lower than the original Millett hybrid design. The FFT below shows that it's dominated by 2nd order harmonic, as expected, with everything beyond the 5th in the noise.



The 5% THD point is about 7V RMS into 100 ohms, or 3V into 32 ohms. If you've ever listened to 3V RMS into a pair of Grados... you've probably suffered long term hearing damage. For comparison, the Millett hybrid design clips at 2-3V RMS into pretty much any load.

The frequency response is quite flat, to the limits of my sound card. On the HP analyzer it measures about -2dB at 20Hz into 100 ohms, and -1dB at 100kHz. LF response at lower load impedances is limited by the size of the output cap. You can always make it bigger of you want.



The AC output impedance is pretty low, measuring about 3 ohms.

This amp will drive pretty much any headphones. I've used it with Sennheiser HD600's, AKG K701's, and Grado SR225's - all sounded good.

Just for kicks, I hooked up my notoriously hard-to-drive K1000's to this amp. Wow, I'm surprised... it sounds pretty decent. Surprisingly dynamic. Actually, really good. Wow...

Try it - you'll like it! Simple is good!

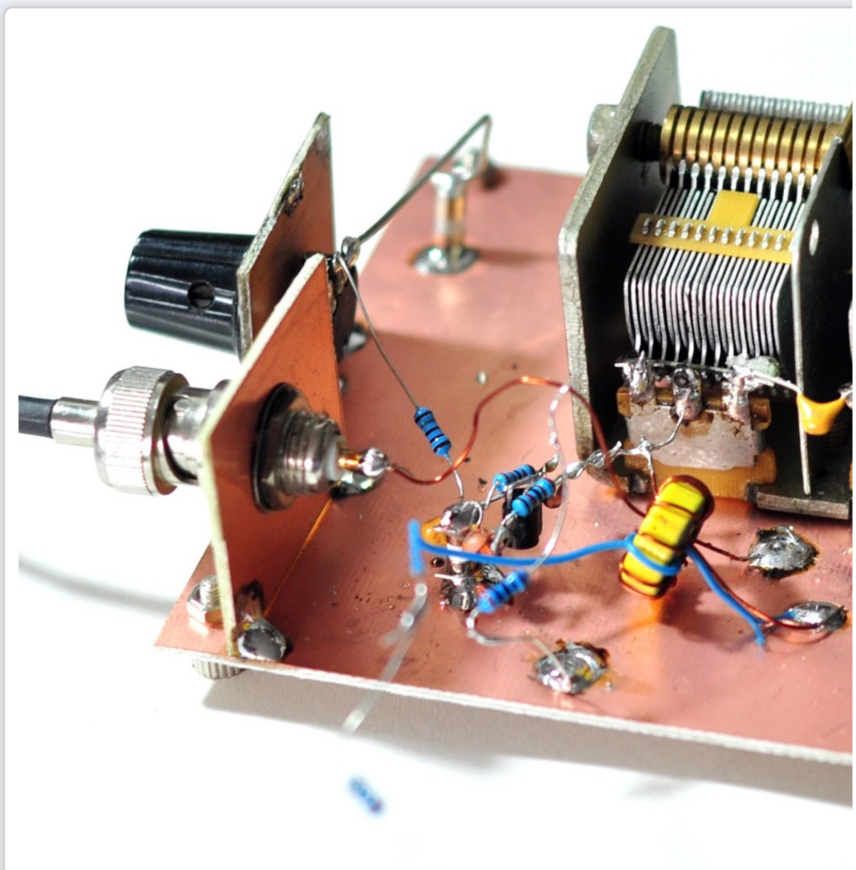
Radio Frequency Experiment by BH1RBG

RF Homebrew Instrument >

Sweep: manual sweep signal source

@8/03, 2015

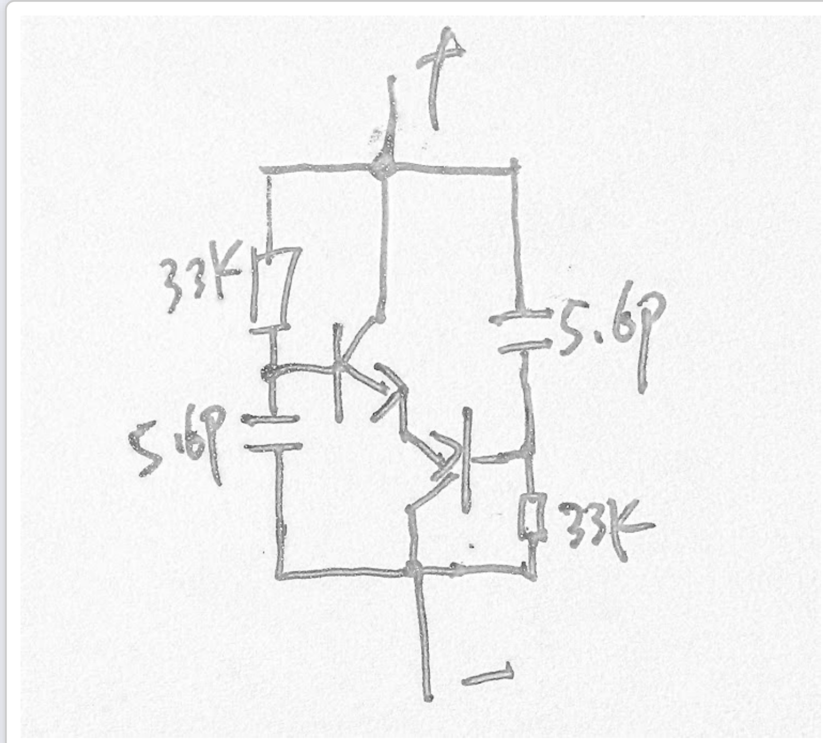
most of time a manual sweep signal source, or just a wind band VFO meet most requirements to checking resonant, roughly check filter response, etc.

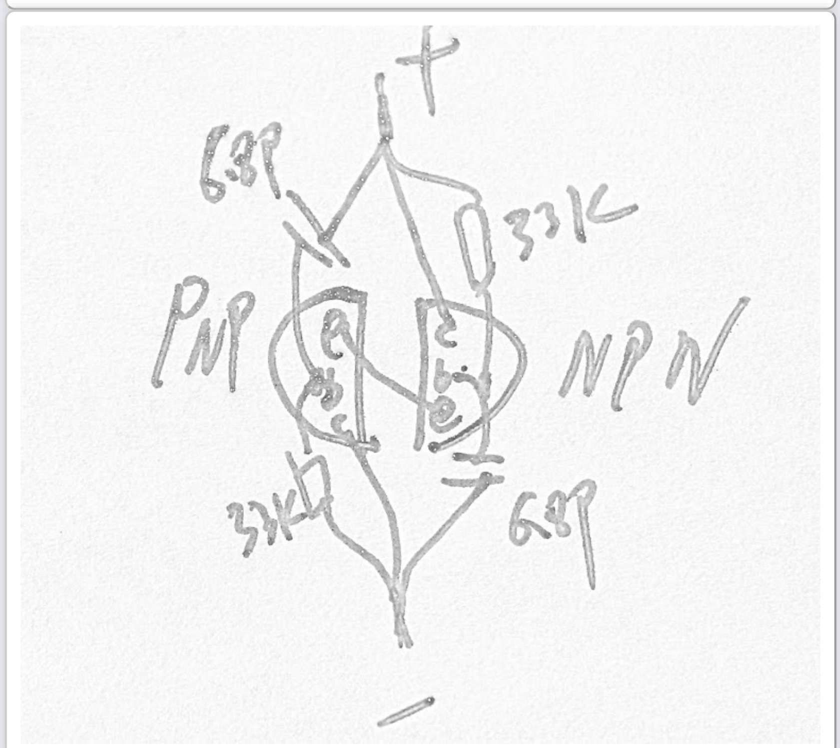


output to a frequency counter is mandatory to check the exactly frequency.

I use the negative oscillator, **New negative oscillator** , construction with 2sc9018(ft>800Mhz, and a 2sc8550, Ft

100Mhz).

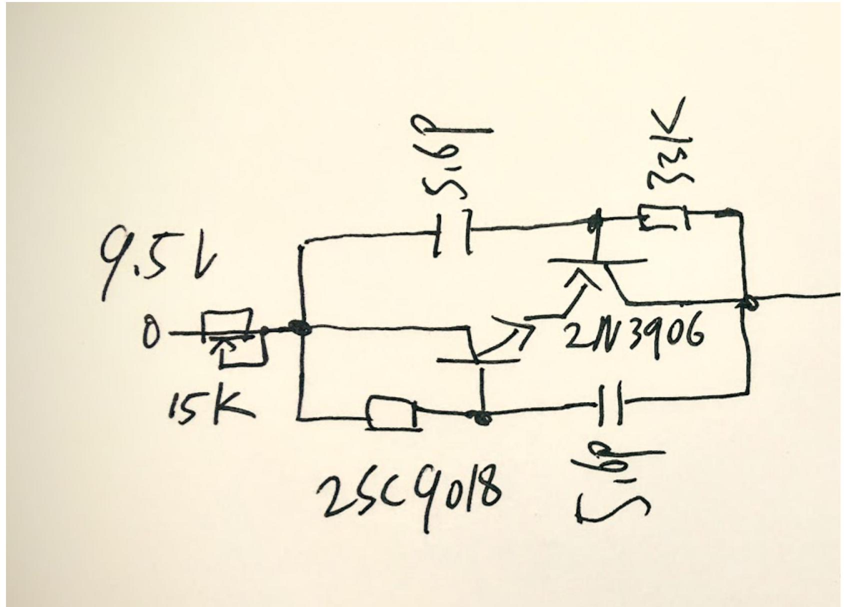




Full schematic (replace the 224 and two variable capacitance diode with air variable capacitor):

Contact me

heyongli@gmail.com



Comments

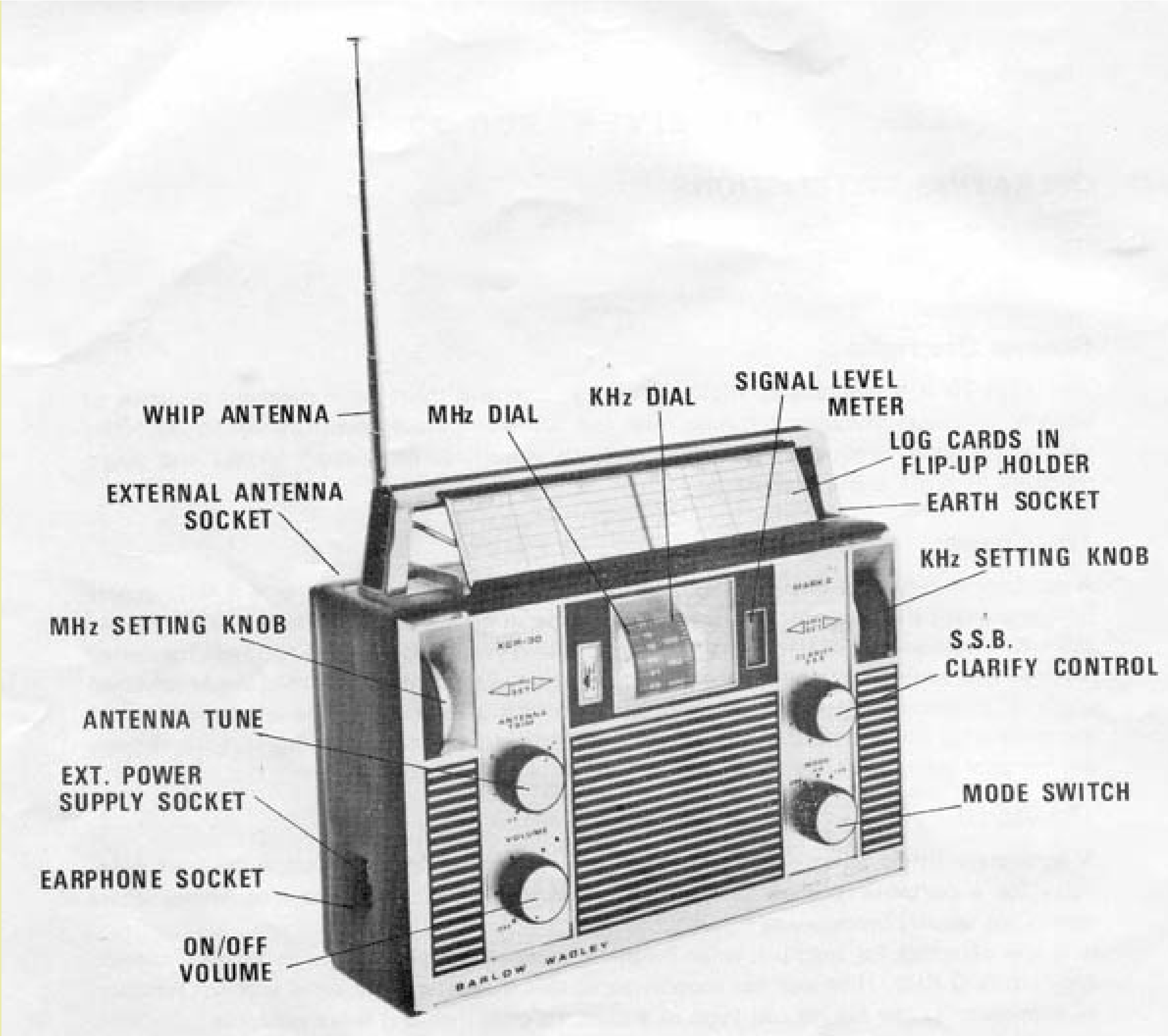
You do not have permission to add comments.

THE BARLOW WADLEY XCR-30 SHORTWAVE RECEIVER

(1980)

The Barlow Wadley XCR-30 portable shortwave receiver with serial number 11270. Frequency stability due to the Wadley loop!

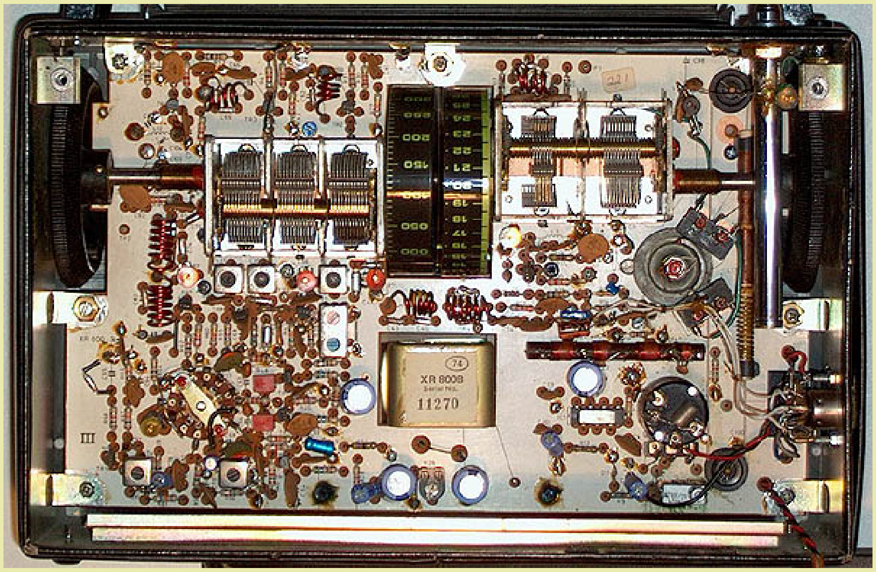
The Barlow Wadley XCR-30 portable shortwave receiver.
This portable shortwave receiver for AM, SSB and CW reception was quite famous in the '70s. When this receiver was designed, there were no DDS and PLL chips available. Therefore, the frequency stability is obtained by the Wadley loop. Many very creative electrical and mechanical solutions can be found in the receiver. The frequency band 0.5 MHz to 30 MHz is covered in 30 bands of 1 MHz. Compared to similar receivers of those days, the frequency stability and reception quality is very good and the analog frequency scale quite accurate (10 kHz). Tuning to an SSB station is not difficult due to the fact that the whole shortwave is split into 30 bands of 1 MHz and the clarifier.



The receiver is portable but quite heavy. However, there is one advantage compared to modern receivers: battery current is only 15 to 25 mA! I used the receiver a lot during holidays and weekend trips but never had to change the batteries because they were empty, only because they were old! Even now, 30 years old, the receiver works good, it never had to be repaired or adjusted. Only the switches have to be cleaned now. And of course, you can see that the receiver is used very much, not only the switches should be cleaned...

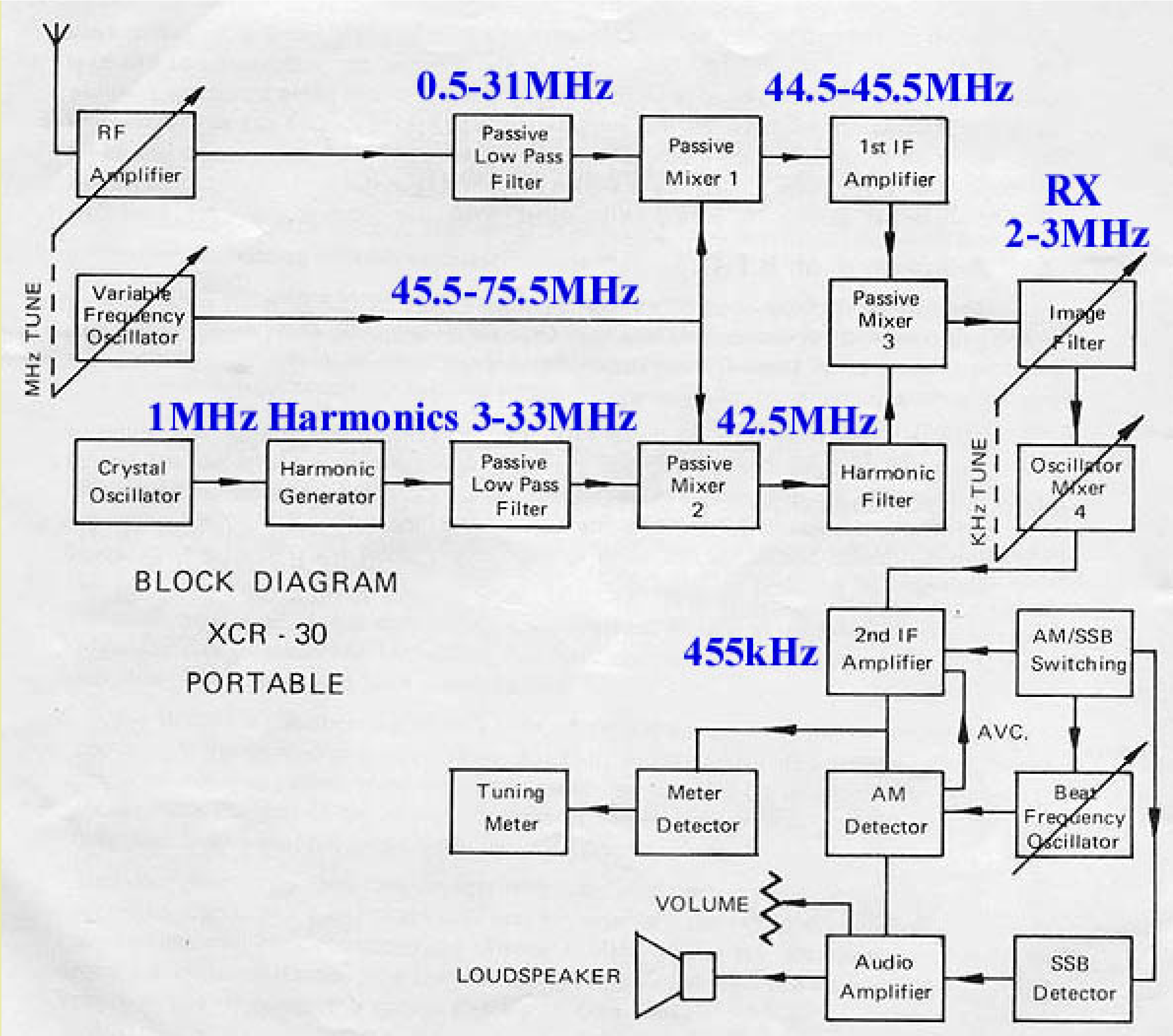
This receiver is used very often!
It was worth its price of 160 Euro that I had to pay for this second hand receiver in 1978!
I always took it with me while on holidays when camping, sailing or staying in a hotel. This receiver is used for listening to national broadcasts on the shortwave during holidays abroad, for listening to coastal traffic on 500 kHz (Morse), 2182 kHz (Speech), weather forecasts of coastal stations during sailing, radio amateurs during holidays or at home in the garden, or it is tuned to my favourite AM broadcast station.

Old technique with many complex mechanical components and adjusments.
Many mechanical components had to be used for the realisation of the receiver with Wadley loop. All the tuning is done by variable capacitors. The selective bandpass antenna filter at the input is tuned by permeability tuning, a core moves up and downwards into a coil. Parts of the coil are switched by micro switches. The tuning knob for this bandpass antenna filter does move the core and also activates the micro switches.
Big mechanical dials are used to read the frequency. There are many bandpass filter coils and trimmers that have to be adjusted. It was indeed quite a complex radio with many mechanical parts.



Variable capacitors for the MHz and kHz tuning, permeability tuning with micro switches for the bandpass antenna filter (right side).

Explanation of the receiver and the Wadley loop.
In principle, it is a receiver from 2 to 3 MHz. The whole band 0 MHz to 31 MHz is converted to this frequency range in 1 MHz steps.
The Variable Frequency Oscillator (VFO) should be tuned close to 45.5, 46.5, 47.5,......73.5, 74.5, 75.5 MHz, depending on which 1 MHz range between 0 MHz and 31 MHz you want to receive. In passive mixer 1, this desired 1 MHz range is converted to the 1st IF of 45 MHz (44.5 - 45.5 MHz). In passive mixer 2, a harmonic from the 1 MHz harmonic generator is also converted with this VFO signal to a 42.5 MHz amplifier. In the passive mixer 3, this 42.5 MHz signal converts the 1st IF downwards to 2 - 3 MHz, the 1 MHz tuning range of the basic receiver.
If the VFO drifts a little in frequency, the 1st IF and the 42.5 MHz signal do also drift with the same value but the difference (the 2 - 3 MHz signal) will not change! So the stability of the 2 - 3 MHz output signal of passive mixer 3 is only dependent on the stability of the 1 MHz crystal oscillator!



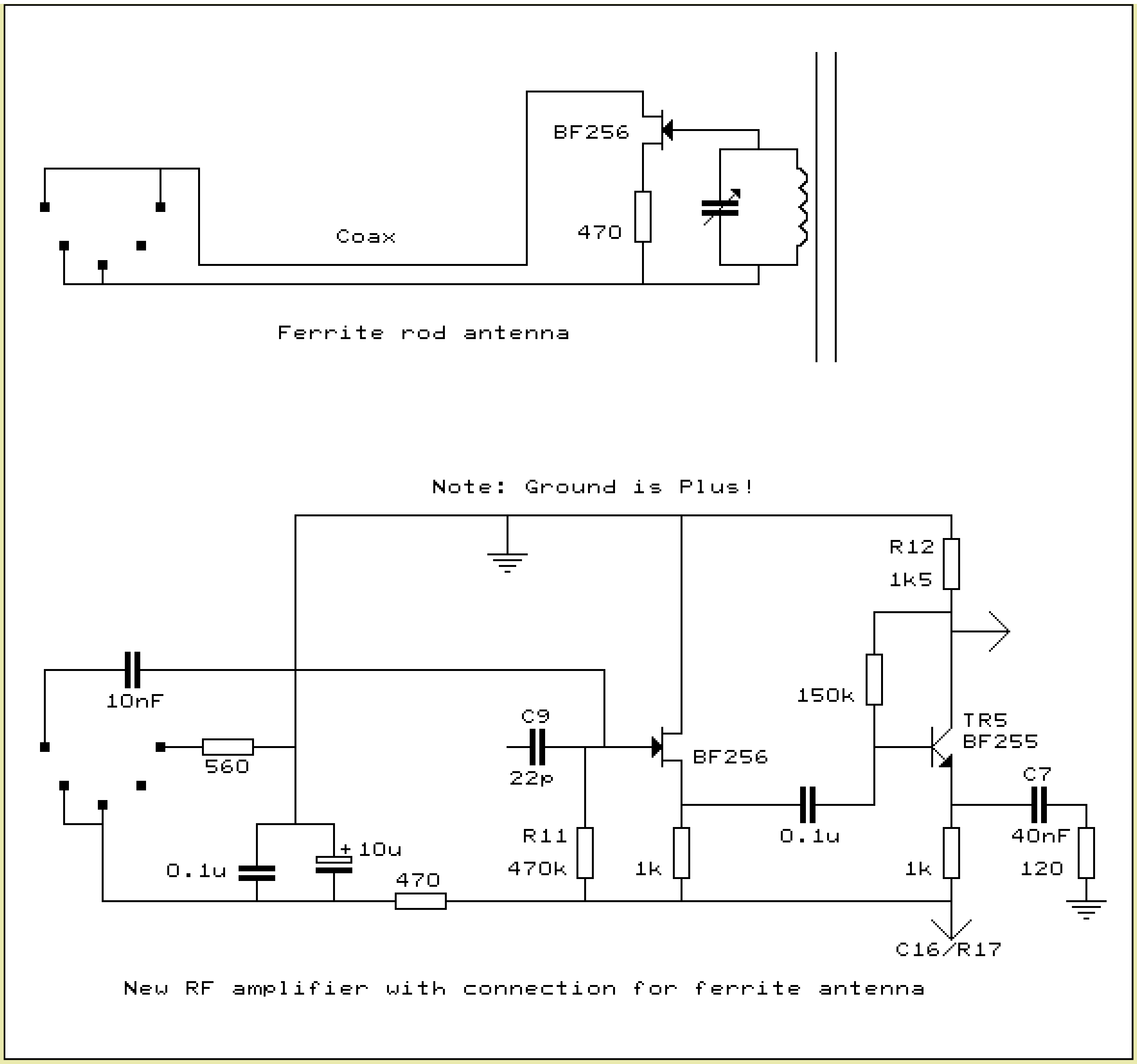
Block diagram of the receiver

Click here for the schematic diagram of the receiver

Modifications.

- The 5 pF capacitor C1 was replaced by a trimmer so that it can be adjusted to even lower values than 5 pF to prevent overloading the receiver when using my long wire antenna.
- A FET was added to the transistor RF amplifier to increase the Q-factor of the selective antenna filter.
- The gain of the RF amplifier was reduced. The sensitivity was quite high, there was much intermodulation caused by very strong shortwave signals in the evening. The reduction of the RF gain solved these problems, especially when using a wire antenna instead of the telescopic whip antenna.
- A connection for an external ferrite rod antenna for medium wave and long wave reception with active preamplifier was made. The sensitivity is very good with this ferrite rod antenna, much better than with the whip antenna. Long wave reception is also possible with this modification, not with the original receiver. Navtex on 518 kHz and longwave beacons between 260 and 400 kHz that are (were) used by ships and aircrafts can also be received.

And that was it all. These modifications are not something an unexperienced amateur should do. Therefore, I only give here the diagram of that modifications without a detailed story about how to do it.



The circuit diagram of the modifications.
RF gain can be increased by decreasing the 120 ohm.

The connector for the ferrite rod antenna
for medium and longwave reception.

Performance
For a portable receiver, the performance is good. You can receive 95% of wat you want to hear. And it is certainly NOT a battery eater, so a perfect receiver for portable use! Even when compared to modern portable receivers, it is one of the best there is, although the technique is old.
A problem is however that the 1st IF is 1 MHz wide, all kinds of strong signals are present and mixed in the 1st

IF and the 1st and 2nd mixer. Therefore, dynamic range and intermodulation are not as good as that of a modern base station receiver with a narrow filter after the 1st mixer. However, that is not so important for a portable receiver with a telescopic antenna.

Stability is good enough for SSB but not as good as that of a receiver with DDS and PLL technology. That is due to the fact that the VFO and BFO of the 2 - 3 MHz basic receiver are free running L/C oscillators. The analog frequency scale is not as accurate as a digital display.

But the receiver is designed for portable use and should not be compared with a base station receiver for use in the shack. I was always very satified about the performance. With the addition of the external ferrite antenna, it is also an excellent receiver for the medium wave, even indoors!

SPECIFICATIONS

FrequencyCoverage	:	500 KHz to 30 MHz continuous.
Frequency Scale Accuracy	:	Within 5 KHz at all frequencies.
Resetting Accuracy	:	Within 1 KHz at all frequencies.
Modes of Reception	:	A.M., L.S.B., U.S.B., and C.W.
Selectivity	:	6 KHz overall RF on A.M. 3 KHz overall RF on S.S.B. and C.W.
Audio Output	:	0.5 watt (150 Hz to 3 KHz) External phone socket provided (8 ohm min.)
Frequency Stability	:	Will hold an A.M. transmission in tune indefinitely. Will hold an S.S.B. transmission on pitch for long periods of time.
Sensitivity	:	Antenna circuit thermal noise audible at all frequencies.
Image Rejection	:	50 dB on all movable image channels. 60 dB and better on immovable.
Antenna	:	Self contained whip antenna. External open wire socket and earth.
Power Supply	:	6 type "D" (1.5v) dry cells (9 volts) External power socket provided for 6 to 12 volts with internal regulation.
Current Consumption	:	20 mA quiescent.
Weight	:	4.14 Kg. (Including batteries) (9 lbs. 2 ozs.)
Dimensions	:	292 (w) x 190 (h) x 98 (d) mm. (11½" x 7½" x 3⅞")

Specifications.

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Muh

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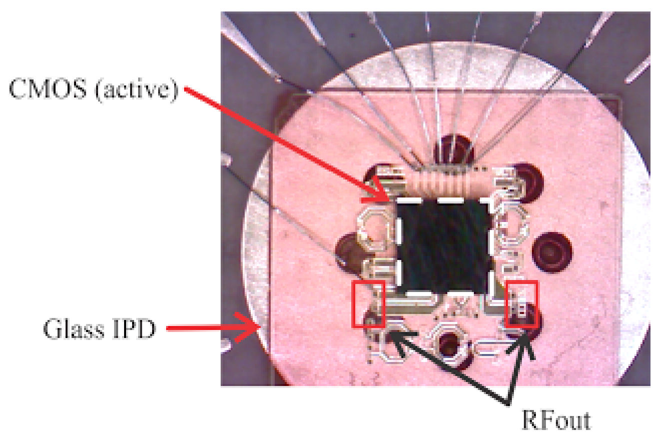
Research

Current Research Interest:

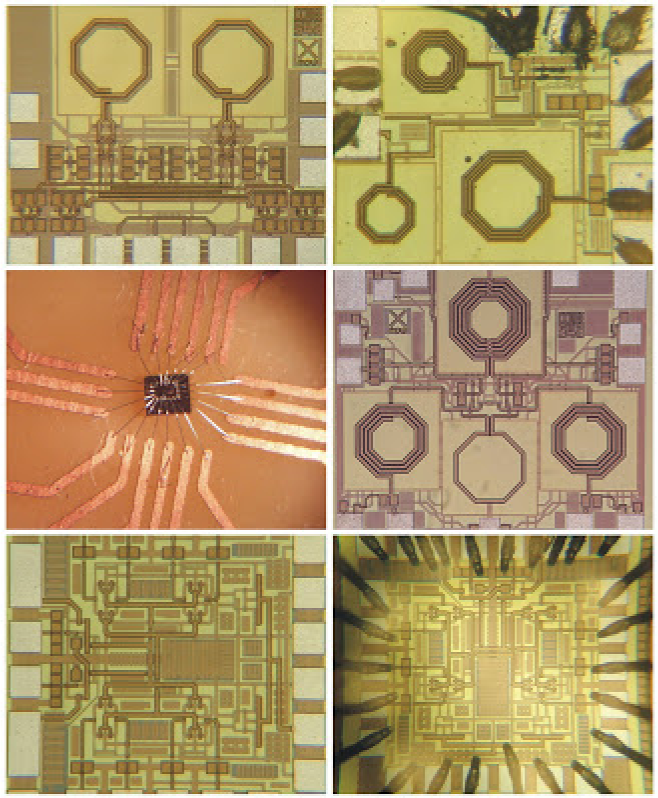
- Advanced High-data-rate Transceiver
- Monolithic Design
    - CMOS Power Amplifier
        - Switching-mode PA
        - Doherty / Seq. PA
        - Class-O PA
    - VCO
        - Amplitude-balanced VCO
        - Low Phase Noise VCO / QVCO
    - Variable Gain Low-Noise Amplifier, Sub-Harmonic Mixer
- Energy Harvest
- Multiport transceiver

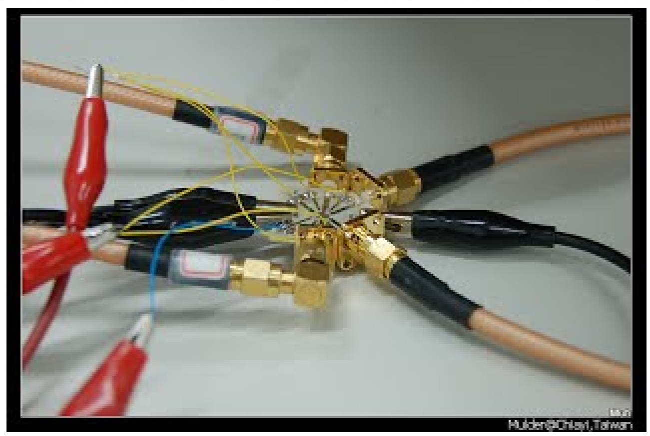
Something fun

MMIC:

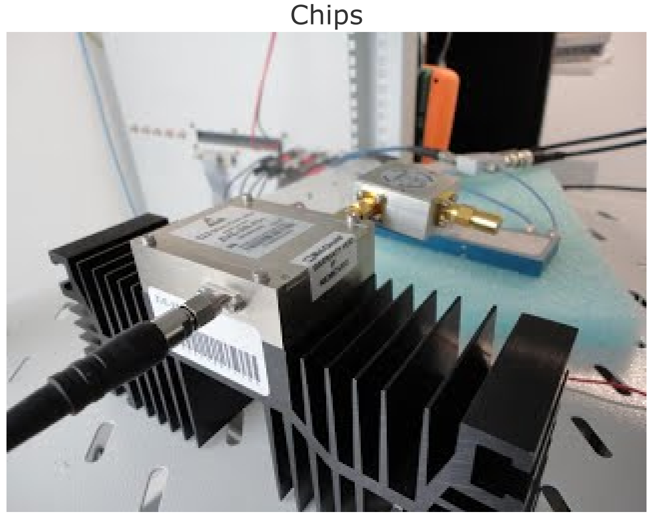


Flip-chip assembly of CMOS and Integrated Passive Device (IPD)



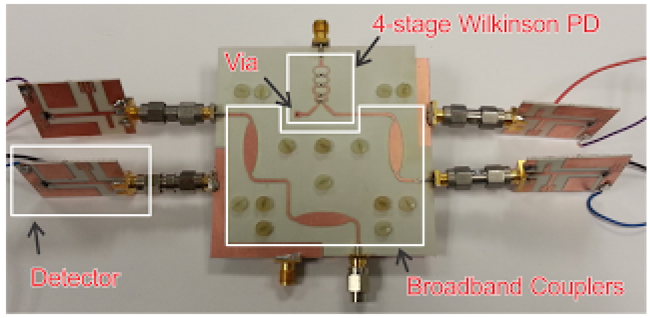


Chips

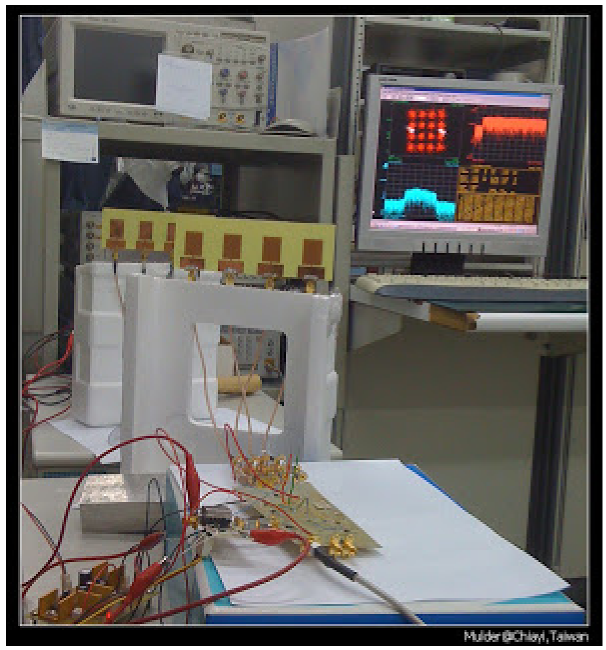


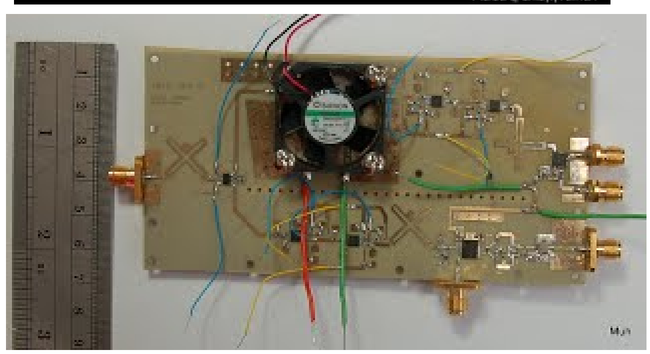
Measurement of CMOS PAs

Discrete RF:

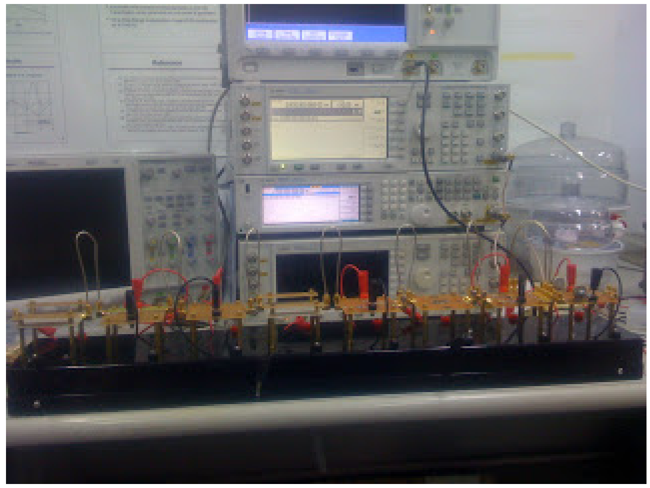


Ultra-wideband six-port receiver based on microstrip-slot directional coupler





MIMO 4G/LTE transceiver prototype



Reconfigurable RF transceiver for education purpose

Exhibition of the reconfigurable RF transceiver

Economic portable spectrum analyzer

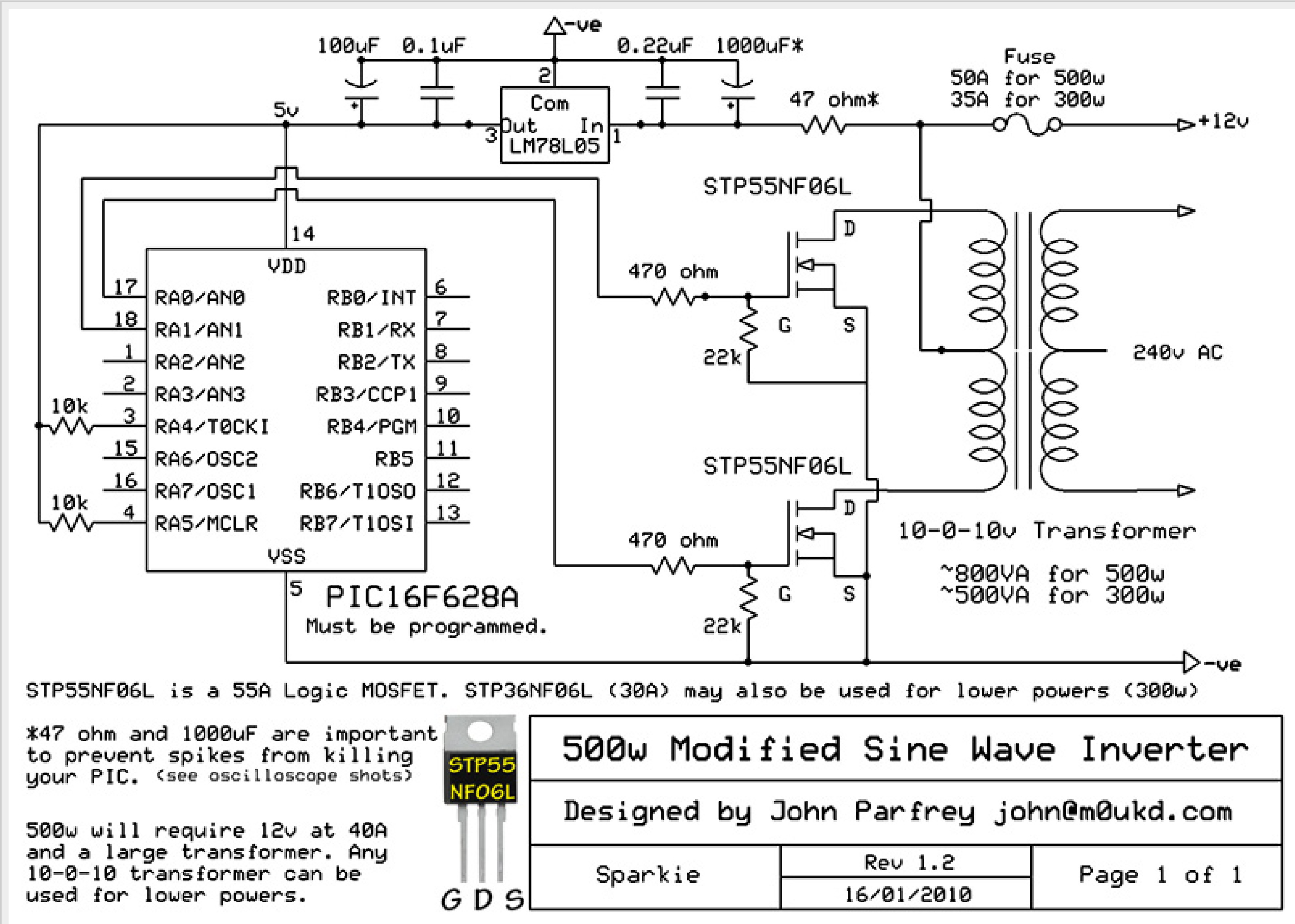
Ultra Low-Noise Ampilfler (NF < 0.5 dB)

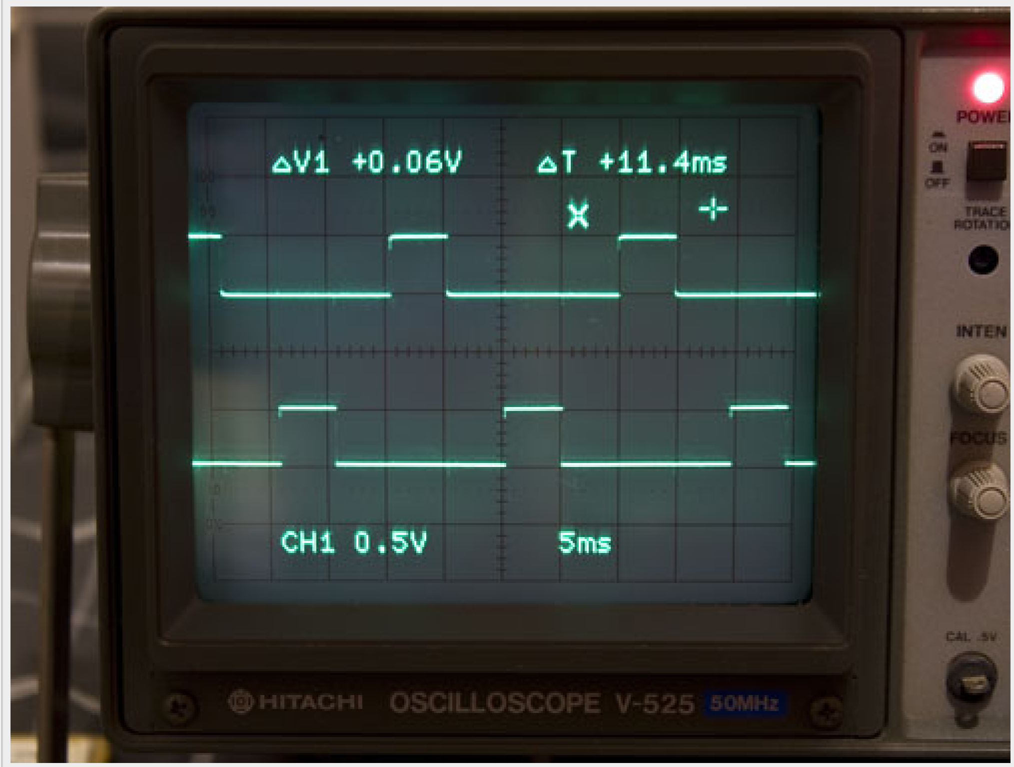
Classics Papers:

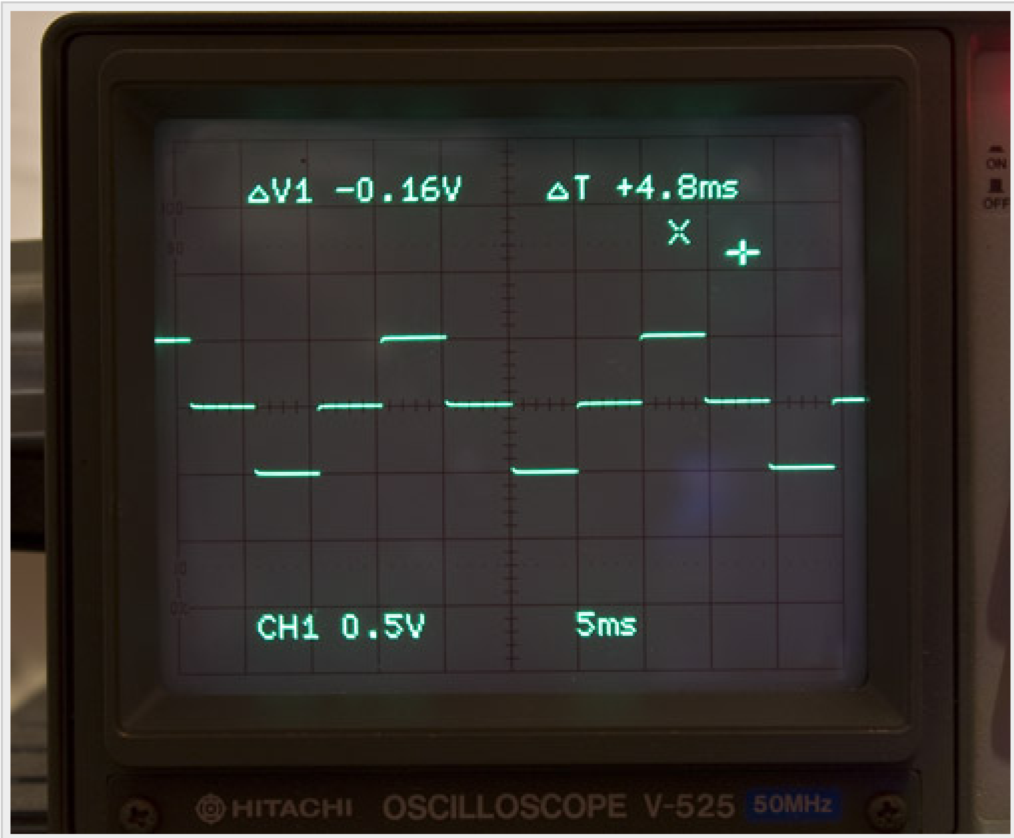
- Passive
  - Multistage Wilkinson PD [**by Cohn**]
  - Multistage BLC [**1** , **corr**]

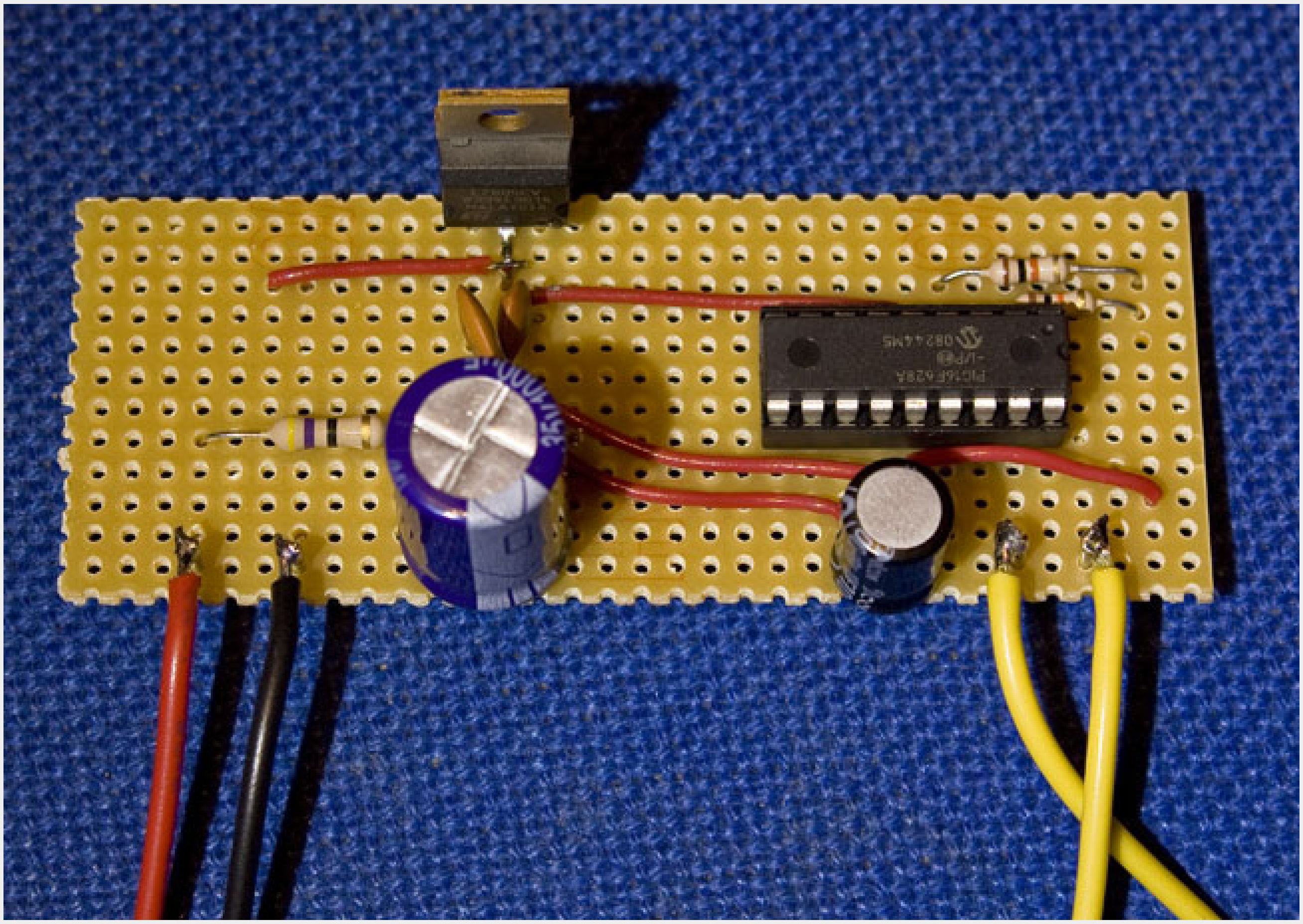
- Gysel Combiner [**1, Gysel**]
- Active
  - LNA [**1, Shaeffer**]
  - VCO [Hajimiri], []
  - PA, linear [], switching []
- Multi-port, four-port, five-port, six-port
  - [Engen's papers in 1977]
  - []

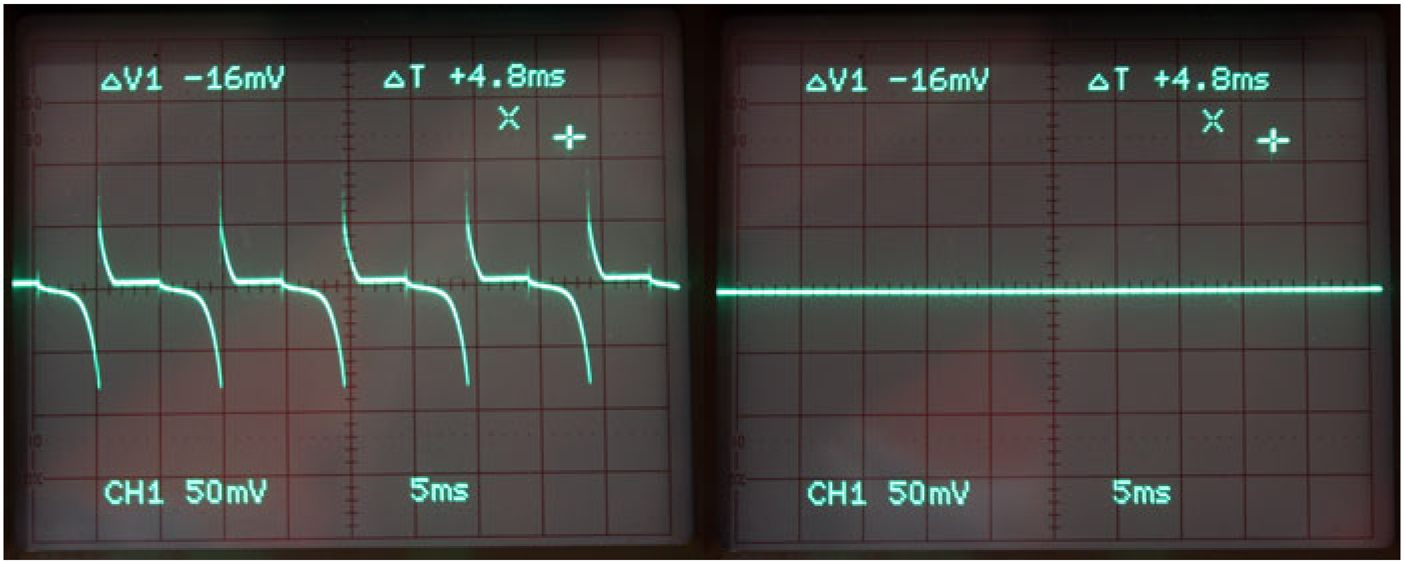
PIC controlled 500w ‘Modified Sine Wave’ Inverter




ΔV1 +0.06V
ΔT +11.4ms
CH1 0.5V
5ms
POWER
ON
OFF
TRACE ROTATION
INTEN
FOCUS
CAL .5V
HITACHI
OSCILLOSCOPE V-525
50MHz


△V1 -0.16V
△T +4.8ms
CH1 0.5V
5ms
HITACHI OSCILLOSCOPE V-525 50MHz

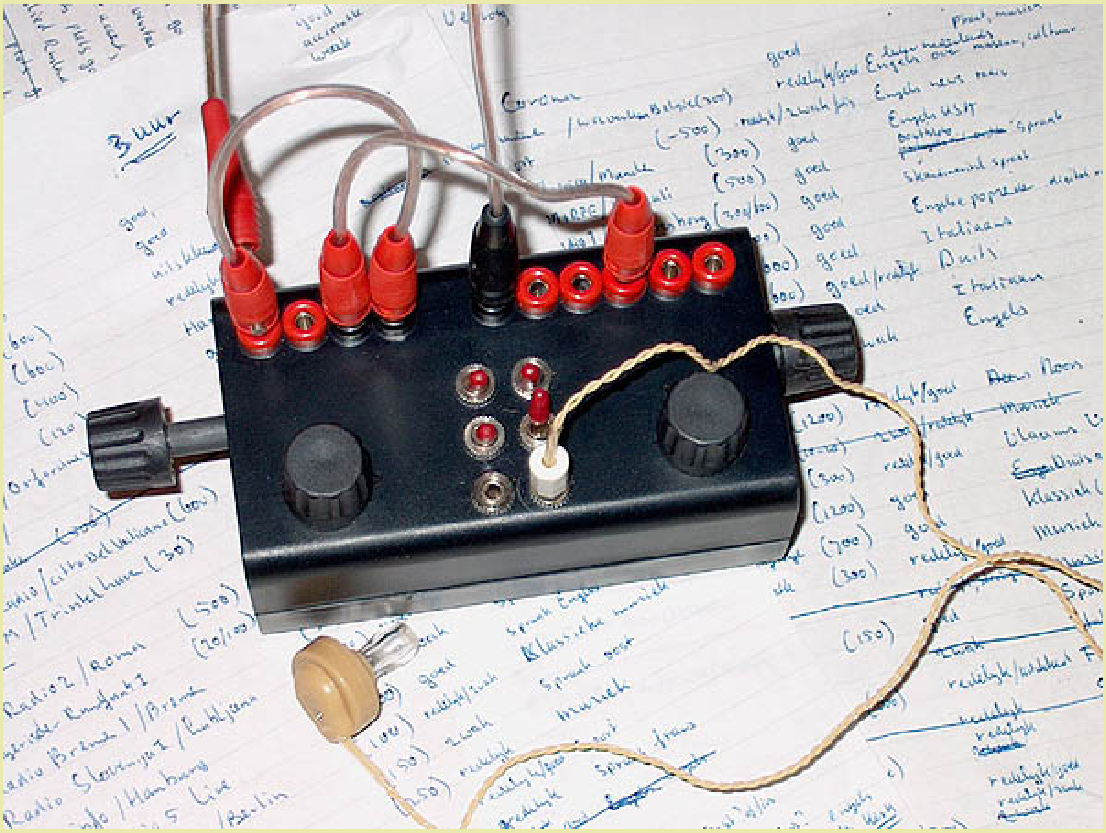




Disclaimer: This circuit provides high voltage so great care should be taken not to become a part

IMPROVED CRYSTAL RECEIVER FOR THE MEDIUM WAVE (AND SHORTWAVE)

(2003)



The improved crystal receiver.

WHAT YOU CAN HEAR WITH SUCH A SIMPLE CRYSTAL RECEIVER

All stations are heard **without using any amplifier!**
Just the passive diode detector and crystal telephone are used with a 20 meter long wire antenna at a height of 4 to 5 m!
Total listening time during 2 days was only 3 to 4 hours!

Frequency	Station	Power	Quality	Remarks
621	RTBF-Belgium (Waver-Overyse)	300	acceptable	031129 French
648	BBC Worldservice (Orfordness)	500	good	031128 English
675	Arrow Radio The Netherlands (Lopik)	120	good	031128 Dutch + Music
693	BBC Radio 5 Live	150	acceptable	031128 English
747	Radio 1 The Netherlands (Zeewolde)	400	strong	031128
765	Radio Suisse Romande (Sottens)	600	strong	031129 Music + French

801	Bayerischer Rundfunk 1	100	acceptable	031128 Deutsch + Music
846	RAI Radio 2 (Roma)	500	acceptable	031128 Italian
864	France Bleu (Villebon sur Yvette)	300	good	031129 Music + French
873	AFN Power Network (near Frankfurt)	150	good	031129 Sport USA
900	RAI Radio 1 (Milano)	600	good	031128 Italian
909	BBC Radio 5 Live	-200	good	031128 English about sport
918	Radio Slovenija 1 (Lubljana)	300	good	031128 East European
927	RAI Radio 1 (Milano)	600	good	031128 Italian
927	VRT Radio 1 Belgium (Wolvertem)	300	good	031129 Vlaams about football
936	Radio Bremen (Bremen)	50	weak	031128 Music
945	France Info (Toulouse)	300	acceptable	031128 French
954	CZE Cesky Rozhlas	300	good	031129
963	Radio Finland (Pori)	600	acceptable	031129
972	NDR info (Hamburg)	100	weak	031128 Deutsch
981	Radio Varna?? Bulgary (Varna)	150	weak	031128
990	Deutschland Berlin (Berlin)	100	acceptable	031128 Classic music
1053	Talksport UK	-500	acceptable	031128 Sport
1062	DRP3 Denmark (Kalundborg)	250	acceptable	031128 English
1089	Talksport UK	400	good	031128 English about sport
1134	Voice of Croatia (Zadar)	600	strong	031128
1143	Voice of Russia (Bolshakovo)	150	acceptable	031128
1179	Sveriges Radio 1 (Solvesborg)	-600	good	031128 Swedish?
1188	VOA / RFE Hungary (Marcali)	500	good	031128
1197	Voice of America (Munchen)	300	good	031128 English
1215	Virgin Radio UK	-200	good	031128 English + Music

1296	BBC Worldservice (Orfordness)	500	strong	031128
1314	NRK1 Norway (Kvitsoy)	1200	good	031129 Norwegian language?
1332	RAI Radio 1 Italy	300	acceptable	031128 Italian
1386	KAL Voice of Russia (Bolshakovo)	1200	good	031129 German
1395	Radio 10 FM The Netherlands (Trintelhaven)	30	good	031128 Dutch + Music
1395	Radio Tirana (Fllake)	500	strong	031128
1422	Deutschland Funk (Heusweiler)	600	good	031128 Deutsch
1440	RTL Radio (Marnach)	-1200	acceptable	031128 Deutsch
1467	Transworld + Vatican (Roumoules)	1000	good	031128 Music, various languages
1494	Voice of Russia (St. Petersburg)	600	acceptable	031128
1512	Vlaanderen Belgium (Wolverthem)	300	good	031128 English, Dutch
1530	Vatican Radio (Citta d. Vaticano)	600	good	031128 Italian
1539	Evangeliums Rundfunk (Mainflingen)	700	good	031129 Classic music (opera)
1630	Radio Corona The Netherlands	?	good	031128 Local Pirate station

What is the trick
That is an extra antenna tuner to improve the selectivity and sensitivity!
And there is the fading! Stations vary considerably in strength due to fading. Sometimes they are quite strong for a few minutes, then they disappear and other stations can suddenly be heard. So be patient, keep listening, tune the antenna tuner to maximum sensitivity or selectivity and let the fading do its work.

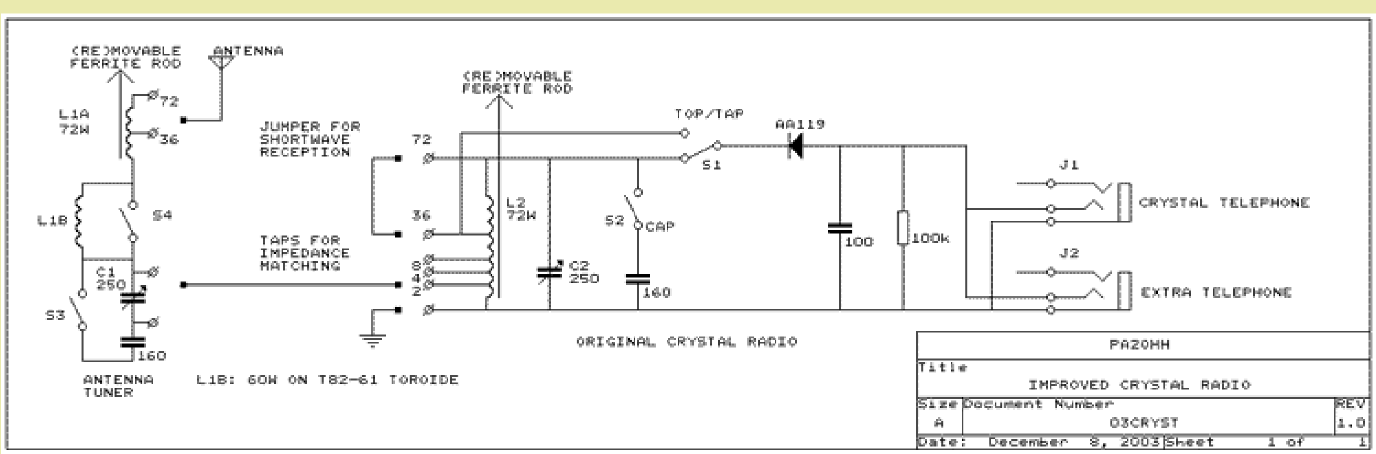
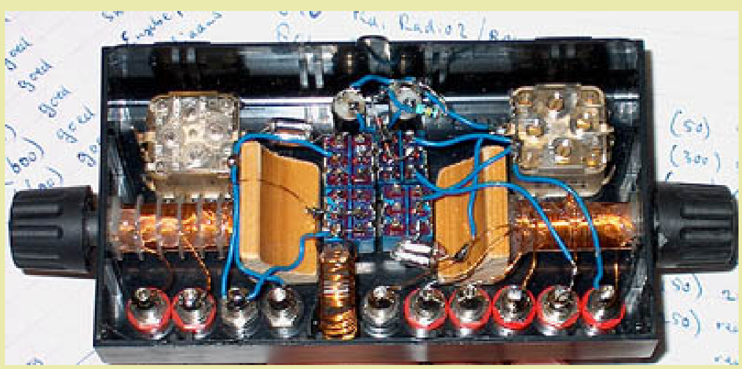


Diagram of the improved crystal receiver with antenna tuner.
big diagram

Top view

Description
This passive receiver is a combination of an antenna tuner with an original crystal receiver. The antenna tuner improves the sensitivity and selectivity considerably as it tunes the antenna to resonance for the reception frequency. It also suppresses breakthrough of shortwave stations.
The tuner and receiver coils are wound on 8mm ferrite rods (0.3 mm copper wire). The rods are provided with a knob and movable, so the value of L1 and L2 can be varied by moving the rods in and out the coils. For shortwave reception they are removed completely.
With L1B (switch S4), the inductance can be increased for the lower end of the medium wave band, the capacitors C1 and C2 can be increased with an extra 160 pF with S3 and S2. With S1, the diode can be connected to a tap instead of the top of L2. Below 1 MHz, the top position was the best one, the tap did only decrease the sensitivity without affecting the selectivity. Above 1 MHz, the tap gave the best selectivity without losing sensitivity.
S2 is added to cover the frequency range below 750 kHz as the value of the variable capacitor was too low or the number of windings of L2 should have been a little more... Connect the tuner part with a jumper wire to that tap of L2 that givest the best selectivity or best sensitivity.



Inside view

How to use the antenna tuner
The antenna tuner tunes the antenna to resonance. Impedance matching is done by choosing the optimum tap of L2.
With jumpers, the tuner can be used in 3 ways:

1. L1 and C1 in series. This is the preferred method with maximum selectivity. Tuning is done by C1 and L1A. Selectivity is maximal if L1B is switched in series with L1A.
2. L1 only, for the lower frequency range if it is not possible to tune the antenna with method 2. Tuning is done by moving the ferrite rod in and out L1A.
3. L1 and C1 in parallel, for the lower frequencies and short antennas (see first picture). Tuning is done by C1. However, use of this method should be avoided, take one of the next two if possible.

However, it depends on the antenna etc. which combination is the best. And of course you need a (good) ground system! I use the central heating for that.

The diode
I did some experiments with schottky and germanium diodes. The germanium diodes were always better, but please look at various articles on the internet about diodes for crystal receivers. I took the AA119 that was available here in the "museum" box. A very old OA81 showed similar performance. The resistor of 100 k after the diode gave good results and is not critical.

Medium wave and Shortwave reception
It is possible to receive the medium wave and shortwave. For shortwave reception, the ferrite rods are removed. It is also possible to connect the antenna directly to the lowest tap of L2 without using the antenna tuner. Shortwave signals are very strong! For the higher shortwave frequency bands, shorten the taps 32 and 70 with a jumper (ferrite rod removed of course).

Headphones instead of the crystal telephone
Quite good results were obtained with normal hifi stereo headphones instead of the crystal telephone. A 230 to 6 or 12 volt transformer was used for impedance matching. The primary 230 V was connected to the output of the crystal receiver, one earpiece (or two earpieces in series) are connected to the secundary 6 or 12 V. Sound quality was better, sensitivity not much less than with the crystal telephone. However, it will depend on the type of transformer and headphones you are using. The 100 k resistor can be removed.

Radio with digital display for identification of the stations

Tools for Medium Wave DX ing with the crystal receiver
I use a (non connected) headphone over the crystal telephone to eliminate background sound. It also holds the crystal telephone on its place.
For identification of the stations, a simple digital portable receiver is very useful to determine the exact frequency. But be careful, some stations are on more than one frequency!
On the internet you can find the European Medium Wave Guide (search for European Medium Wave Guide). Very useful of course to identify the stations when you have found the exact frequency with the digital receiver.

Improved, but it can still much better!
This is only an improved crystal receiver, not a top performance design. But as you can see from the table of received stations, the results are not bad, 45 stations received during listening for only two evenings (3-4 hours totally). On the internet you will find a lot of information about how to make a real top performance crystal receiver with balanced armature headphones (often called sound powered headphones), very high Q coils etc.

BTTF contest!
In December 2003, a contest was organized here in the Netherlands. The name was Back To The Future (BTTF). The challenge was to log as many medium wave stations as possible with a passive receiver.
Click HERE if you want to download the zipped bttf2003.doc log of the stations I heard with this crystal receiver during that contest.

Hanging up the antenna is a real outdoors activity!

BACK TO INDEX PA2OHH

[DIY Audio Home]

Data for the low-voltage hybrid headphone amp (AudioXpress 11/02)

PLEASE READ - Commercial usage of information on this site:

I consider all the information that I post here to be in the public domain. So, you can use it however you want, for commercial or non-commercial use.

That said, I would appreciate it if you at least let me know if you are going to use any of the circuits or especially PCB Gerber files to make commercial products, or to sell bare PCB's.

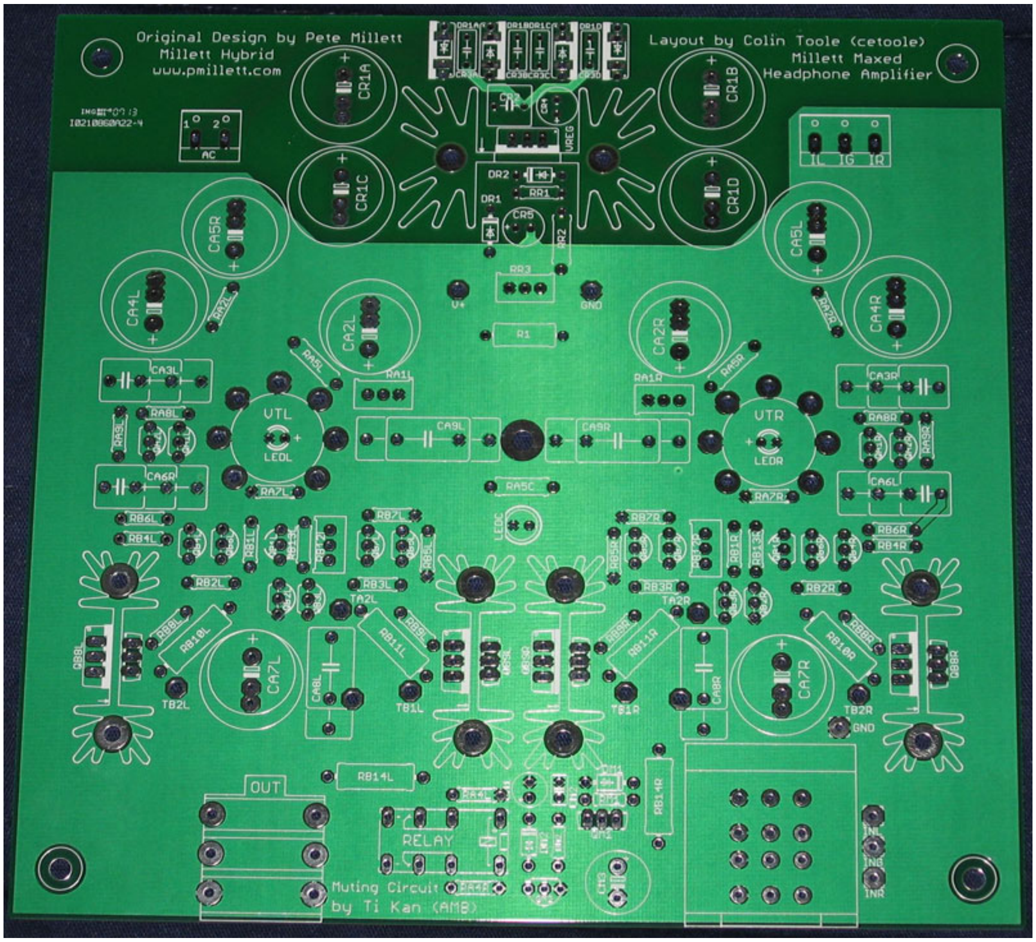
There are some cases where products are being sold not only with my permission, but active involvement. The "Millett Hybrid" effort and others at HeadFi are examples (and excellent models of how the DIY community should work, in my opinion). There are other cases where I have asked vendors to sell PCB's as a service to hobbyists. And there are other cases where companies are manufacturing and selling PCB's, chassis, etc. without contacting me at all.

In ALL of these cases, I make no profit from any of the sales. Zero, zip, nada. I have a normal "day job" that pays the bills, this is strictly a hobby with me. So please do not expect me to provide the level of technical support that you might expect when buying a product. I try and help, but it sometimes takes me days - even weeks if I'm traveling for work - to respond.

Thanks for your indulgence in reading this!

The evolution continues! The "Millett Max" has arrived... details are here.

Here's what the MAX PCB looks like:

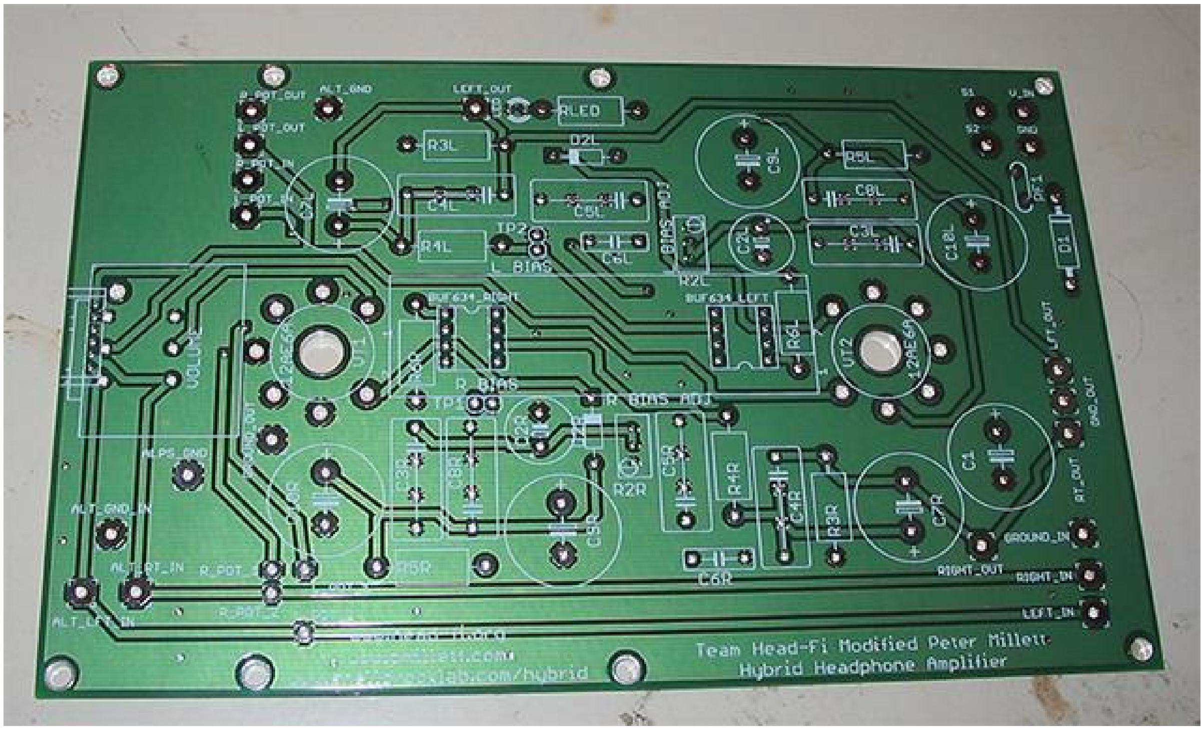


Wow!

A group at [Head-Fi](#) has taken the design and enhanced it, making it more of a high-end, "tweakable" design. Great work guys! This is how DIY audio SHOULD work...

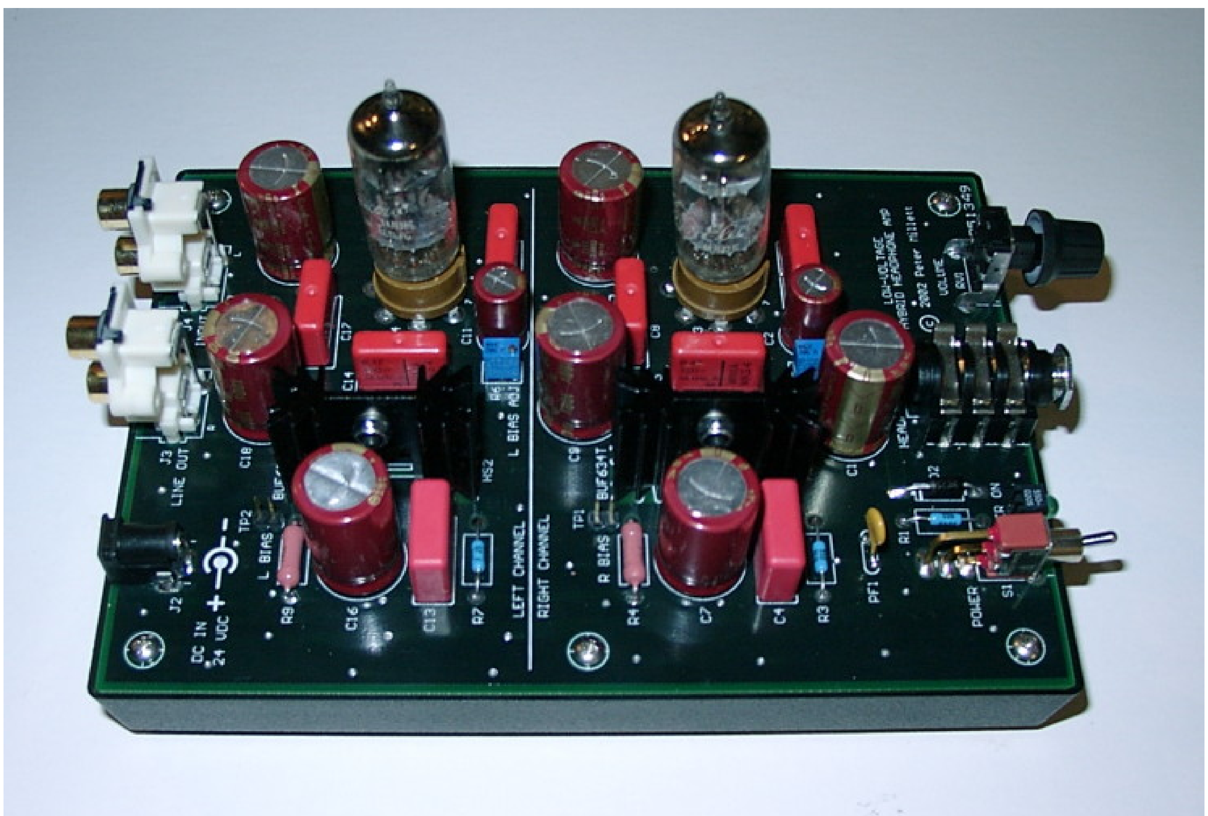
There's full details of this project [on this DIYForums site](#). Cool!

Here's what the new PCB looks like:



You can also download the Gerber files of this version of the board(169k ZIP file) from my site.

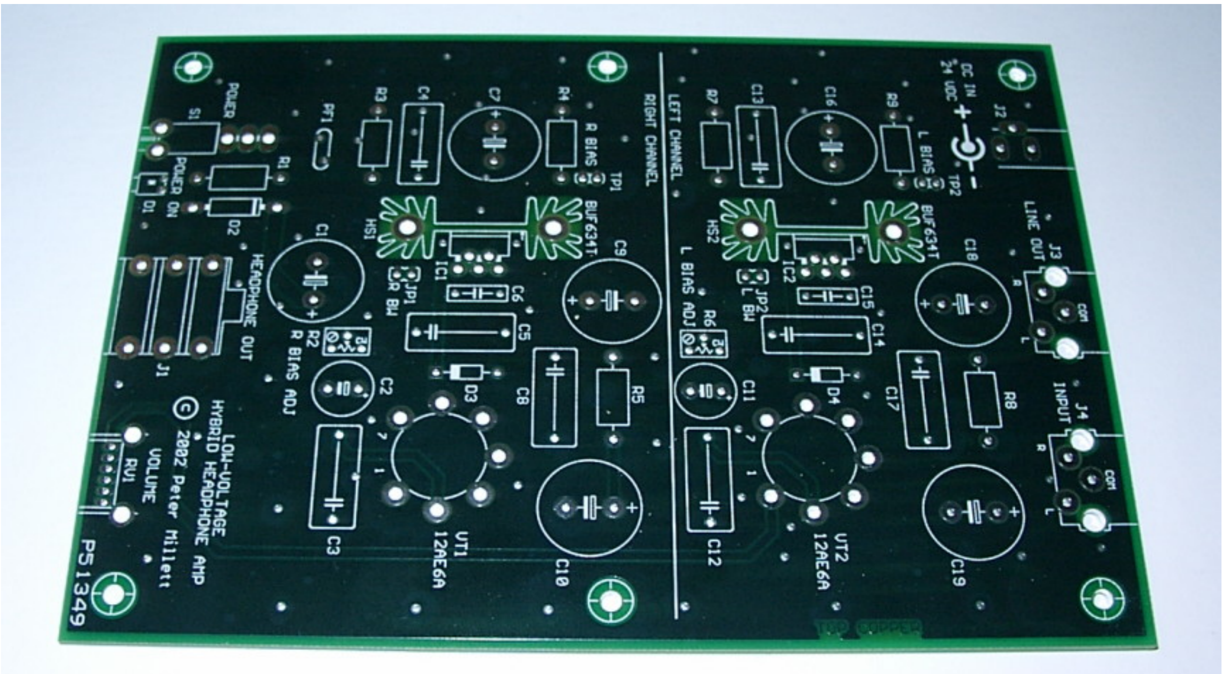
Here's the original...



Thanks to AudioXpress and Ed Dell, the full magazine article is now available for download!

"Build A Low-Voltage Tube Hybrid Headphone/Line Amp (612kB PDF file)

This page contains files to download that relate to the article about building a low-voltage hybrid headphone amplifier that I wrote for AudioXpress issue 11, 2001. This is a great project for the newcomer to tubes, since it's easy to build, and safe - it runs on 24V DC power!



The following files are available for download:

Schematic:

PDF file (176k)

PCB:

ZIP file with Eagle CAD .SCH and .BRD (48k)
ZIP file containing Gerber files to build PCB's (163k)
TIFF file of PCB layout (25k)
TIFF file of top copper (25k)
TIFF file of bottom copper (25k)

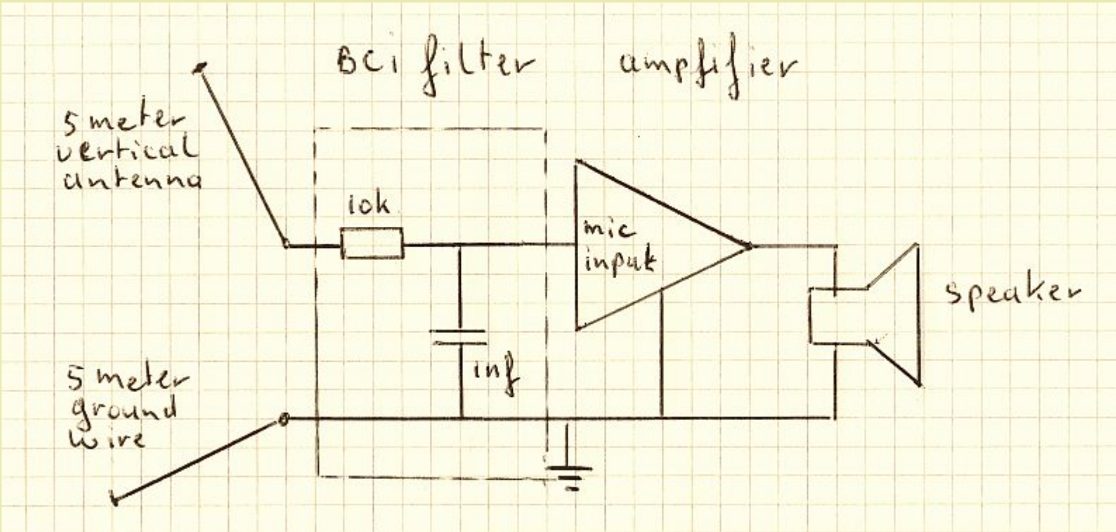
Bill of materials:

PDF file (4k) or Excel spreadsheet (18k)

COLD RECEPTION OF AUDIO FREQUENCIES

(1973)

KLIK HIER VOOR DE NEDERLANDSE VERSIE



The simple idea of the audio frequency receiver.

The idea was simple

Connect an antenna cable to the microphone input of an amplifier and you will hear everything between 20 Hz and 15 kHz (audible audio range) received by the antenna. I was a poor student. No TV or Hi-Fi set with pickup. A good mono radio and an old bike, I did not want to have more. I did like to do simple experiments. To make a 0V0 receiver with a tube, to live a week without a radio, but only with a crystal receiver for the short-wave. And now ... this simple experiment, receiving audio frequencies!

I got the idea after getting an old tape recorder. I cleaned it and it worked fine again. An antenna wire in my room just below the roof was connected to the microphone input. What I heard was hum and mainly broadcast stations, caused by RF signals rectified by the input stage of the microphone amplifier. A BCI filter had to be built in the cassette recorder to suppress the RF signals. And there were some more modifications. The cassette recorder motor was switched off to save power and to prevent interferences. And it had to be possible to listen to the signals via the internal speaker. Very important was that the tape recorder had batteries and could work independently of the mains.

I got an old cassette recorder.

It did eat the tapes and the high frequencies were gone.

In my room in the civilized world

In my room I could only receive 50 Hz hum. And tone messages that were transmitted on the power line, for example to switch on the street lights. Also clicks of light switches and thermostats of for example refrigerators could be heard. So it was clear to me that when I would receive anything else than hum and "man-made noise", then I had to find a place far from the civilization! Admitted, we had skipped the lessons in the drawing of schematic diagrams and designs of printed circuit boards with pen. But that could happen, in 12 years we would have ORCAD!

The first test location was my nice students room.

Far away from civilization in a beautiful winter landscape

With Peter I went to Alex at the countryside to test his receiver, as in his appartment he did not have space for an antenna. Not only Alex, but I also walked barefoot in the snow! A poor student has no boots! The fresh snow was very soft, but also very cold! What a difference with Peter his expensive, warm boots and two pairs of socks! And had his Murphy B40 to be carried by two people, my 0V0 receiver and receiver for audio frequencies could be carried with one finger. Soon I had ice cold red toes and we had hanged up an antenna in the cold snow, made of wire and insulators for electric fence. But also there only 50 Hz hum could be received. There was a perfect deserted place about half a mile from Paul's home. The distance from the antenna to the power line would be about 100 times larger, the 50 Hz hum according to my studybooks 10000x or 80 dB lower and should disappear in the noise. We walked in a beautiful winter landscape, quite a challenge for my bare feet in the snow! But certainly a nice place to receive audio frequency signals undisturbed by hum. No interferences from electric fences because the land is not used during the winter.

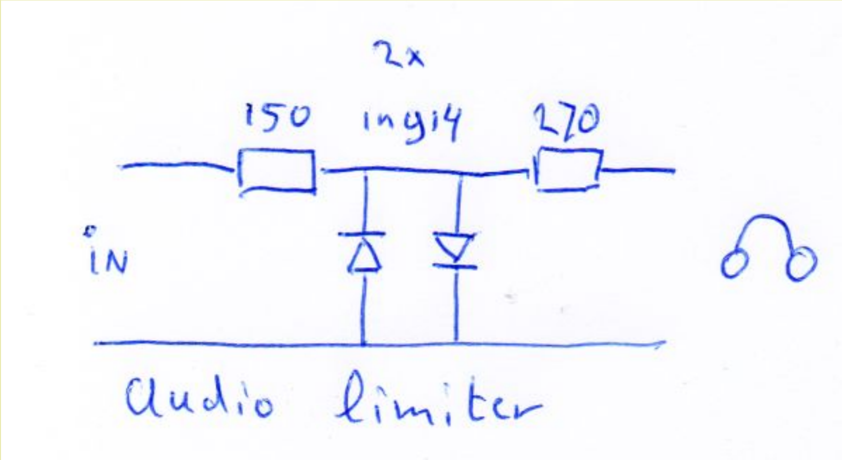
A nice place in a beautiful winter landscape to receive audio frequency signals without any interference.
Of course we had to try to walk barefoot in the snow!
But do not do that when it is colder than -3C to -4C (26F)!

What could be heard?

The antenna was hanged up in a treetop. Really many signals could be heard! All kinds of discharges like thunderstorms and many cracking sounds. We thought that it were discharges between air layers with different temperatures. And also very weak still some 50 Hz hum, probably from a power line a few miles away, although the addition of the three phases should be zero. But I did not hear short whistles around approximately 10 kHz. They should be there too. But perhaps that the other interfering signals were too loud or we did not listen long enough. During a quarter of an hour we listened to these signals, then we went back and talked about other cold things. Like that cold gramophone records sound better, you have to put them in the fridge before you play them!

Funny, ice cold red toes in the snow! What a difference with the indoor life in the city! It was great not only to see this beautiful winter landscape, but also to feel the cold snow with my bare feet! "Why should you wear boots if you can walk barefoot? You're feeling more comfortable and it's even cheaper!" said Alex. Although ... my bare feet needed a few terribly unpleasant minutes to get used to the cold! Peter told that "Barefoot Power" was low power and "With Boots" was

high transmit power. I did not know much then, so I learned something more then! A few years later I was a fanatic radio amateur and I made nice QSO's with a simple 1 watt transceiver. "Little Toe Power!"



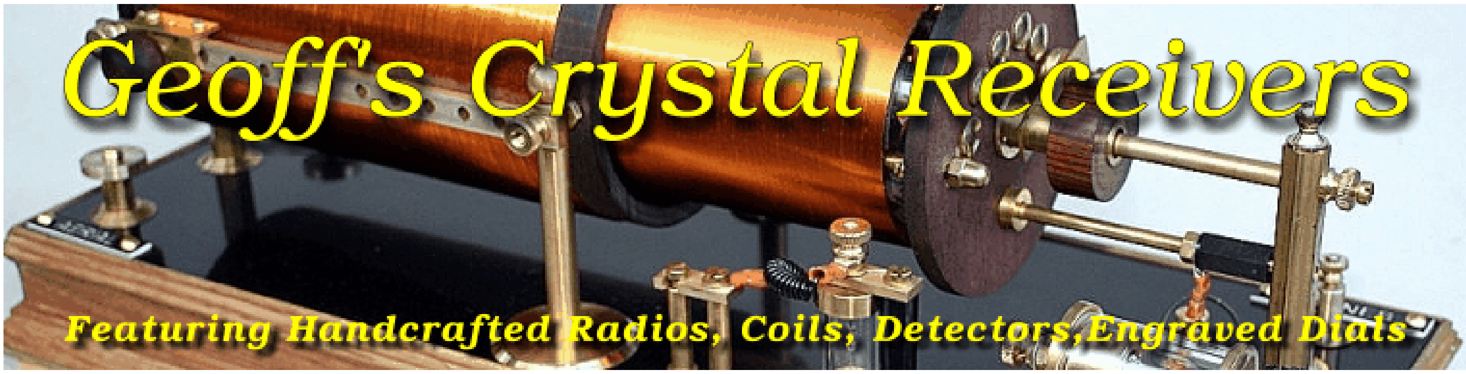
Audio limiter circuit for headphones.

Nice afternoon!
The audio frequency receiver, made with simple means was nice. I did not expect that we would receive so much and such strong signals!
Also the very simple 0V0 receiver with regeneration and one tube was a nice experiment. And you could receive much more than you should expect with such a simple thing. But the reception was not noticeable better than on my students room just under the roof.
Of course, the beautiful Murphy B40 was much better than my 0V0. When I tuned my generating receiver to the B40's reception frequency, Peter did really hurt his ears because of the noise! Later I made a limiter circuit for his headphones.
And I would walk barefoot in the snow more often, after a few times, getting used to the cold became much easier!
I gave the cassette recorder away, so no further audio-frequency reception experiments more.

Modern VLF reception
If you want to know more about receiving audio-frequency signals, please check the following link. They also sell a kit of a receiver with a high impedance antenna input:
https://theinspireproject.org/

Barefoot power!

[BACK TO INDEX PA2OHH]



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- Crystal Sets
- Projects

Geoff's Crystal Sets – Page 3

Variometer Receiver

Please click on the photographs for a larger picture of this beautiful wireless receiver.

Hi Dave (my webmaster), I was going to have a quiet restful Whitsun holiday but it turned out to be one of my busiest. I was quite excited though as I was asked last Thursday evening to make a simple 1920's style crystal radio plus kit of parts for the props department of the Television Series 'Mr Selfridge' on ITV.The set was to be used in one

of the episodes of the series which would be televised later in the year or in January 2016. The deadline for the set to be completed due to the need filming was days away just a little bit short notice but I like a challenge.

The set had to be in character with the early 20's sets but not too commercial looking so no box just an open layout ,a dual slider was hinted at but that would have been difficult in the time scale so I plumbed for a Variometer , also I had no tuning capacitor which would look convincingly 1920's. Variometers were very popular on the earlier sets of the day in UK so I thought I would have a try at making one.

Into the project I plunged friday lunchtime. It all went very smoothly with non of those constructional hitches and this set turned out to be a little gem one of my simplest but neatest sets. I emerged late Sunday night with the completed set and a bag of parts for the props crew to assemble for the edited prop.

There was no post today due to Bank holiday Monday so we arranged to meet up and I handed over the completed set to Faye one of the props crew team of ITV ,she was very pleased.

The Variometer coils turned out better than expected with no snags at all in the winding .I had only made one Variometer before which was on the Acrylic former but this one had to be in character with the 1920's , so I pulled out a piece of 4 inch diameter paxolin I was saving for such a job and wound the coils.They look great dont you think.

I fired up the set on my 132 ft long wire Aerial and It was pretty close to tuning my local radio station considering it was a bit of guess on the number of turns I added a fixed capacitor between coil and Aerial as this seemed the traditional way .The tuning was quite broad as expected but for a simple set it was fine but the visual effect of the large coil was possibly more in key with the original idea. In the day these sets wouldnt need much selectivity or tuning range as it certainly was limited .So as you might guess there was some station overlap and I could here two stations at once . If I had a little more time I would sort out that problem perhaps using a coupling coil for the Aerial.

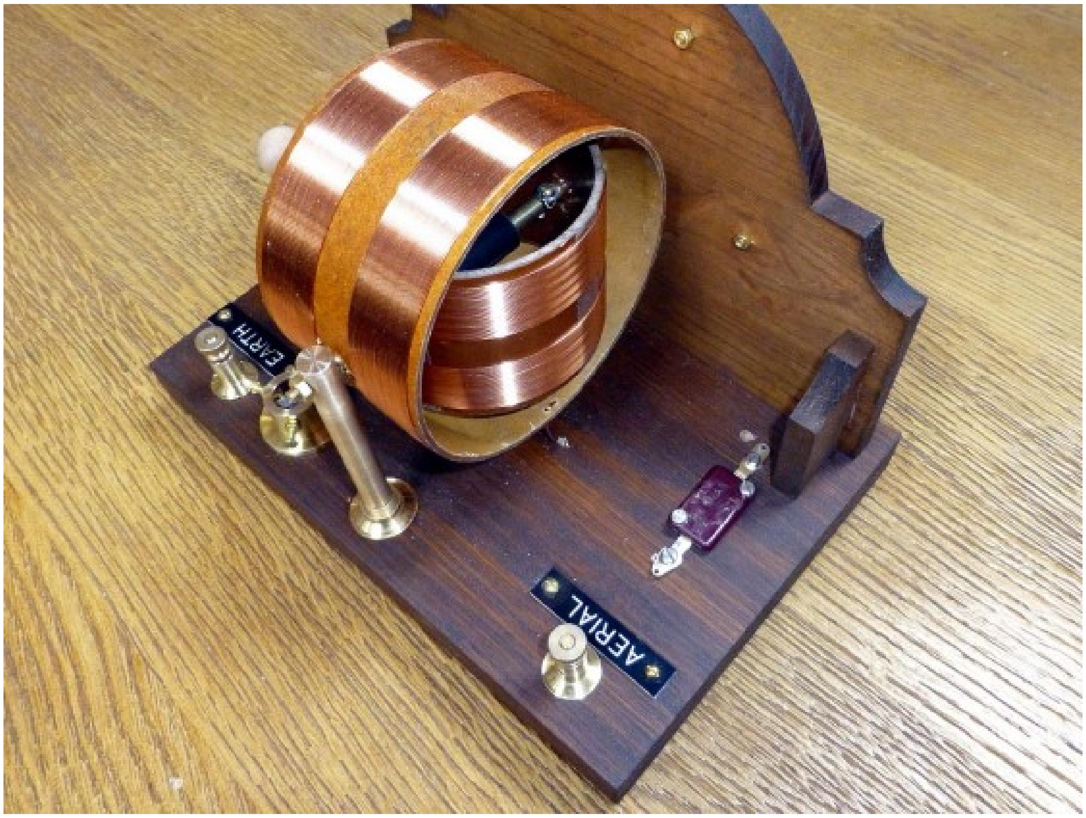
The receiver is made of solid Oak from an old 1920's chest of draws that I rescued from the bonfire pile . I sanded down the old wood and re stained it using one of my antique leather dyes which I discovered was very good on wood as well as leather. Then I used a wood oil finish called 'Danish oil' to seal the grain. The baseboard was 9 inches by 6 inches and 7/8th of an inch thick.I still like to use the old imperial measurements because being Old school I understand them ,its just visually easier than metric measurements to me and just seems right on these older looking sets.

The coil was wound on a 4 inch diameter paxolin former for the outer coil and a 2 1/2 inch for the inner coil. I made all the brass parts to my standard designs on the brass parts page of my website. All the wiring is done under the baseboard. I dont like wires going all over the place on the top of the baseboard. I used one vintage component the aerial coupling capacitor this was from the time period and was made of moulded bakelite made by a company called TCC. I wish I had more of these but they are getting rare. This one was a lovely red coloured moulded bakelite.

The Galena Catswhisker is my standard design which I still sell separately. I also put a diode under the board to quick tune the set instead of fiddling with the catswhisker , its useful when you first need to find a station. All the labels are engraved and not printed the dial is solid brass with the background blacked out so that the numbering stands out clearly and can never wear off.This is how it all used to be done and nothing is from the instant age ,except perhaps the maker LOL.

When I have sorted out a few tuning problems I think I would like to sell this receiver as a kit also as a finished set. It is a visual exercise rather than a highly tuned crystal radio but can still satisfy the listening fascination of the early vintage crystal radios.

Altogether from start to finish from the raw materials this set took two long days to make.



Order Nr.

Slider and Variometer Radio

Click image for larger view.

Having built a few Loose couplers earlier, I wanted to see if I could improve reception by adding tuning capacitors to both coil sections ie. the larger inductance of the main aerial coil on the left of the set and the detector coil on the right. The detector coils on originals has traditionally been a tapped coil however a tapped coil is know to have a much lower Q factor than a straight coil.

So why did they not use a Variometer coil instead? This was always a bit of a puzzle to me. I chose to use an unconventional construction for the Variometer coil being offset arrangement for the inner inductance instead of the standard arrangement of splitting the outer coil into two and having a shaft go through the middle gap for the outer and inner coil. The offset coil is much simpler to make and also gives 180 degrees of dial swing instead of the usual 90 degree swing from minimum to maximum inductance. This arrangement is very rarely seen on the internet searches for Variometers and I just wonder why because the offset method has a much higher Q Factor.

The aerial coil or ATU section was a series tuned arrangement with a slider on top to vary inductance from approximately 1000 micro Henries down to about 50uH plus a 500pF variable capacitor in series with this to give a

tuning range that covers most of the popular broadcast sections of the Medium Wave band. A shorter Longwire is easily tuned by this arrangement.

The Detector Variometer coil had a swing of from about 50uH to 300uH plus a parallel tuning capacitor of 500pF gave me a good tuning range over the whole of the band. The ATU and Detector were mounted on rails so I could reduce the sensitivity of the set for the very powerful Droitwich transmitter 500kWatt and only 30 miles away, this system works out well and I now us it on all of my more advanced crystal sets.

On tune up of this receiver I first used the diode detector and a signal generator set to 1000kHz this position was marked on the ATU coil and tuning capacitor so that I could return to that spot each time. The detector was calibrated in the same way. I would first find a station on the detector coil in maximum position and tune the capacitor to find the station then peak the ATU capacitor for maximum signal.

I found the set to be very sharp and peaky to tune but not easy to calibrate without the use of a signal generator I would have been lost as there are four variables to take into consideration. The overall sensitivity of the set compared to my reference 'Mystery Crystal set' is about twice as loud and far superior in separating stations than conventional single coil and capacitor arrangements. The set arrangement as a whole would only be bettered by using Litz Wire but I wonder if the difference in price would be really justified as this is a first class receiver in standard copper coils and is much more pleasing to my eye esthetically because of the use of attractive metals of brass and copper.

This dual coil and capacitor arrangement is now my favored construction method even on less 'engineered' projects.

Order Nr.

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Radios-3 | Switches | Workshop

DIY Audio Home

An all-tube, 4-pole active crossover

PLEASE READ - Commercial usage of information on this site:

I consider all the information that I post here to be in the public domain. So, you can use it however you want, for commercial or non-commercial use.

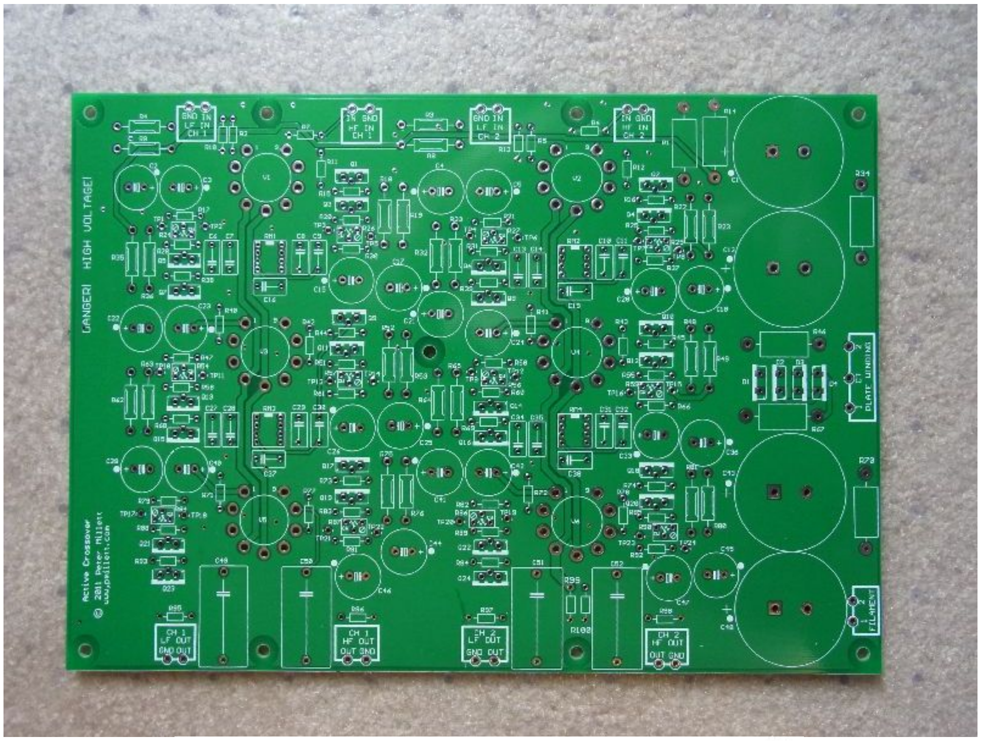
That said, I would appreciate it if you at least let me know if you are going to use any of the circuits or especially PCB Gerber files to make commercial products, or to sell bare PCB's.

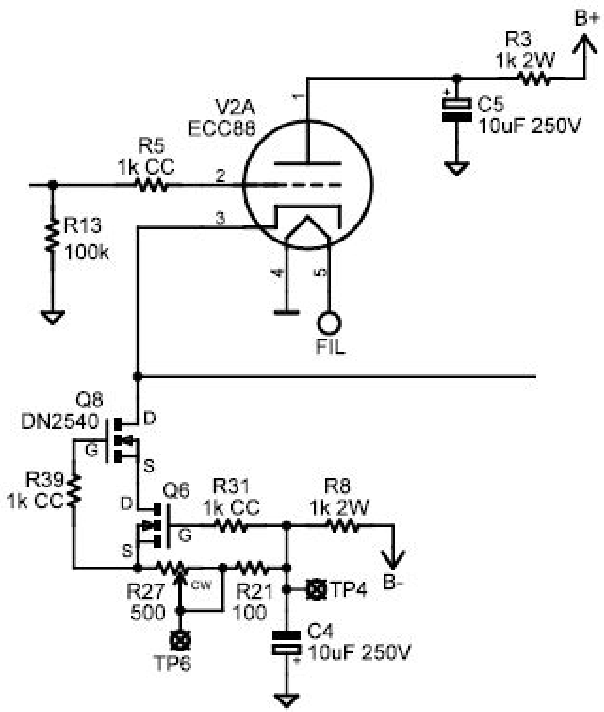
There are some cases where products are being sold not only with my permission, but active involvement. The "Millett Hybrid" effort and others at HeadFi are examples (and excellent models of how the DIY community should work, in my opinion). There are other cases where I have asked vendors to sell PCB's as a service to hobbyists. And there are other cases where companies are manufacturing and selling PCB's, chassis, etc. without contacting me at all.

In ALL of these cases, I make no profit from any of the sales. Zero, zip, nada. I have a normal "day job" that pays the bills, this is strictly a hobby with me. So please do not expect me to provide the level of technical support that you might expect when buying a product. I try and help, but it sometimes takes me days - even weeks if I'm traveling for work - to respond.

Thanks for your indulgence in reading this!

UPDATE 12/19/11 - I had several requests to update this PCB, so I did. The tubes were changed to ECC88 (or anything else that fits that base pinout), and used cascode CCSs (using DN3540s) instead of the resistive loads on the cathode followers.





Now, I have NOT built or measured this myself, but I have provided boards to a couple of people, and reportedly it works :)

I have a couple of pairs of boards left that I'll put up on eBay - if there is interest I'll build more.

Here is an updated PDF schematic. Also, the bill of materials, a PDF of the PCB, and the PCB dimensions.

The rest of the info on this page still applies (like how to set the frequencies).

I originally designed this active crossover with the intent of doing a magazine article about it. I never did write the article, partly for reasons outlined below.

Even though this project turned out exactly as designed, I've never been that happy with it, for a couple of reasons: The main one is that, after building and testing it, I found that I preferred the sound (at least of my existing speakers) with their purpose-designed built-in passive crossovers! I expect that if you had some speakers that were designed to be driven with separate amps and an active crossover, this would be a fine design for it. On paper it performs very well. The only technical area where I am somewhat unhappy with it is that it's a tad noisier that I'd like. I'm sure that this can be addressed, but since I really didn't like the sound in my system, I haven't put a lot of effort into it. I'm sure that a little work on the grounding and worst case putting the power supply in a separate box would cure the problem. I have very sensitive power amps (input about 2-300mV) so it's worse in my system than most.

The design

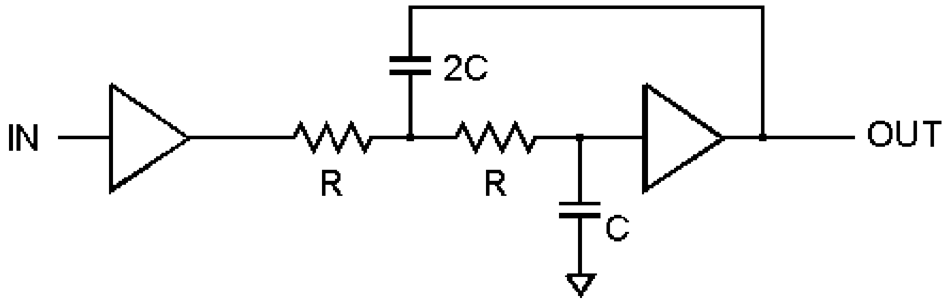
Let me start by saying that I'm not a filter expert. I've certainly designed many active filters in my career, but I don't have an understanding of the complex mathematics involved, so I'm basically a cookbook filter designer. I took standard filter design and put in tubes as the active elements.

For a very good text about designing active filters, look at this from Texas Instruments - "Active Filter Design Techniques", excerpted from "OpAmps For Everyone", also an excellent book. Although this describes filter design using opamps, the principles all apply to tube circuits as well. Another good reference is Application Note OA-26 from National Semiconductor.

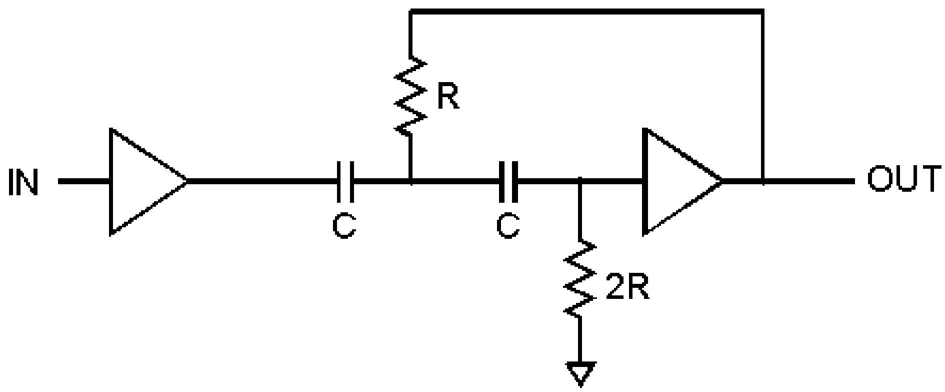
This crossover is a stereo pair of two-way filters (high-pass and low-pass), using a Sallen-key circuit implementing a linkwitz filter. 12AU7 (or 5814) tubes are used as cathode follower buffers between filter sections. It runs on a +/- 100V (more or less) power supply.

The Sallen-Key circuit was chosen for it's simplicity, and the Linkwitz filter is used so that the phase shift through the high-pass and low-pass sections are equal at the crossover frequency. If you have a phase difference between the filters at the crossover, you will get an anomaly in response there (worst case, a "suckout", or deep notch in the response, if there is a 180 degree difference).

In simplified form, the filters look like this:



LOW-PASS FILTER SECTION



HIGH-PASS FILTER SECTION

The amplifiers are shown as generic blocks. In practice, they could be implemented with an opamp follower, a transistor emitter follower, FET source follower, or (as in this case) a tube cathode follower. They are all unity gain amplifiers with high input impedance and low output impedance, and their purpose is simply to keep anything connected to the output (which may be another filter stage) from loading, and thus changing the response of, the filter section. Note that there are also active filter circuits that employ gain... most opamp active filters do.

Each of these filter section is a 2-pole filter. There is a mathematical origin of this term "pole", but you can think of each pole existing because of a capacitor (or inductor). Since there are two capacitors in both the low-pass and high-pass circuits, each are two-pole filters. Note that a single RC filter is a single-pole filter, and an LC filter is a two-pole filter.

A filter has an ultimate rolloff of 6dB per octave (an octave is a doubling of frequency) per pole, so a 2-pole filter has a rolloff of 12dB/octave. If you cascade two 2-pole filters, you get a 4-pole filter, which rolls of at 24dB/octave. This crossover is exactly that: 4-pole filters (one high-pass and one low-pass per channel), using two cascaded 2-pole filters as shown above, to get a rolloff of 24dB/octave. In this example, with a crossover frequency of 2300Hz, the high pass would be down 24dB at 1150Hz, and the low pass down 24dB at 4600Hz.

The capacitor shown as "2C" has twice the capacitance of the cap "C", and likewise the resistor shown as "2R" has twice the resistance of the resistor "R". For details about these component values, see below.

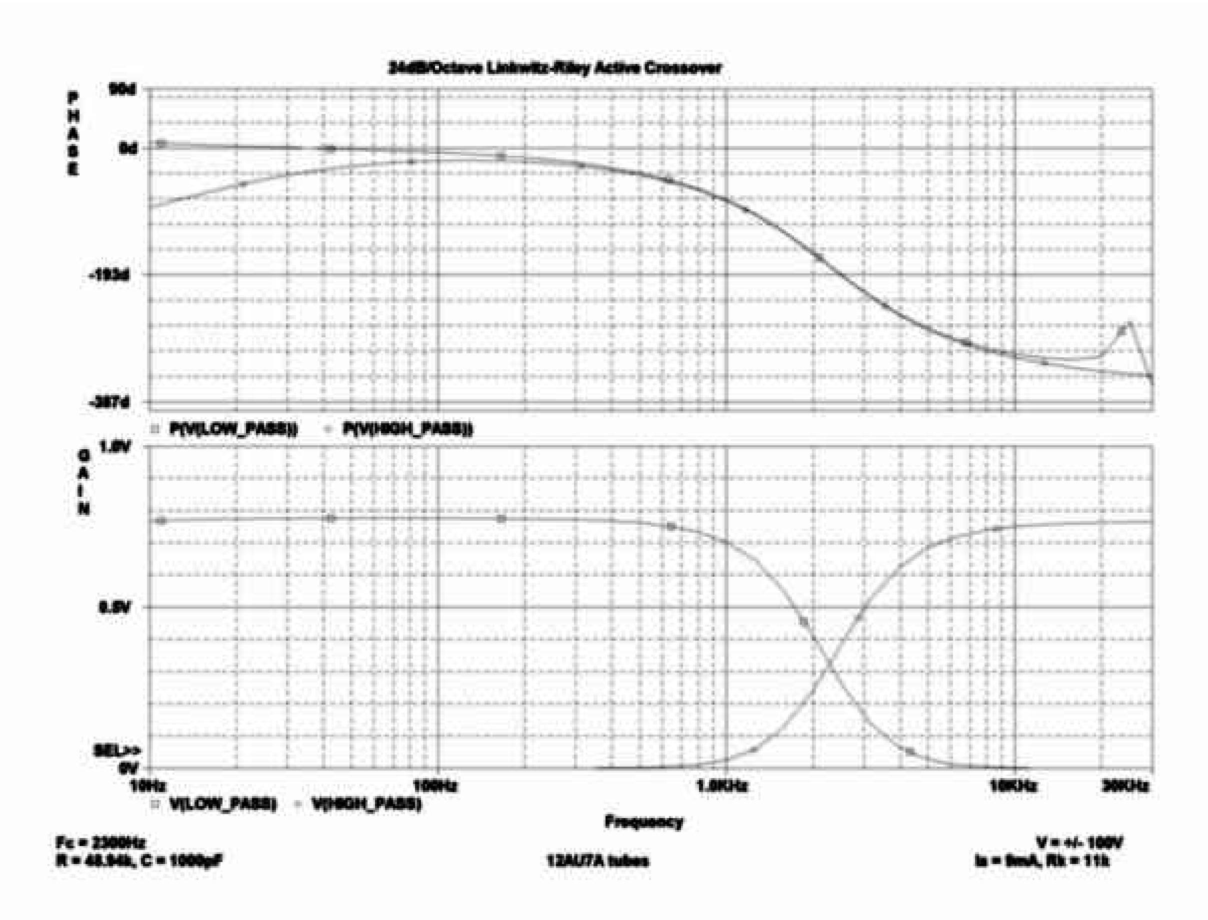
Here is the schematic for the entire active crossover (263kB PDF file)

And a BOM in .XLS or .PDF form - sorry, not very detailed, just what Eagle CAD kicks out.

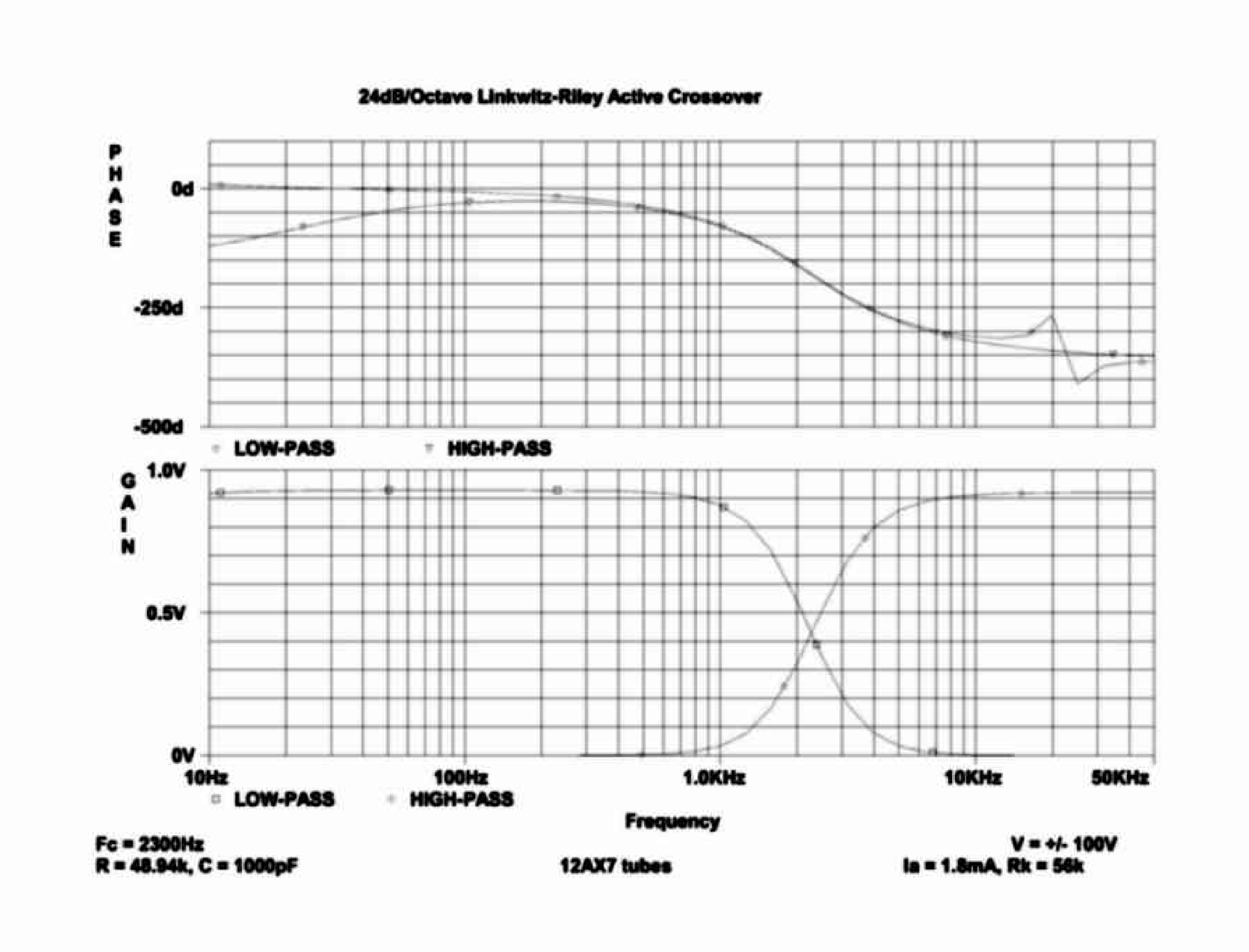
The frequency-determining elements are all resistors and capacitors. I put the resistors on little DIP headers so that it would be easy to change them, to change the crossover frequency. Most normal frequencies can be accommodated by just changing the resistors, but some might require different capacitors. My circuit was set up to cross over at 2300Hz.

Refer to the section below about [Setting Crossover Frequency]() to figure out hot to set the frequency for your application..

I ran spice simulations for the circuit, using both 12AU7 tubes (running at 9mA) and 12AX7 tubes (running at 1mA). The resultant gain/phase is shown below:



Simulation result, 12AU7. [Click here for a more readable version (83kB PDF file)]()

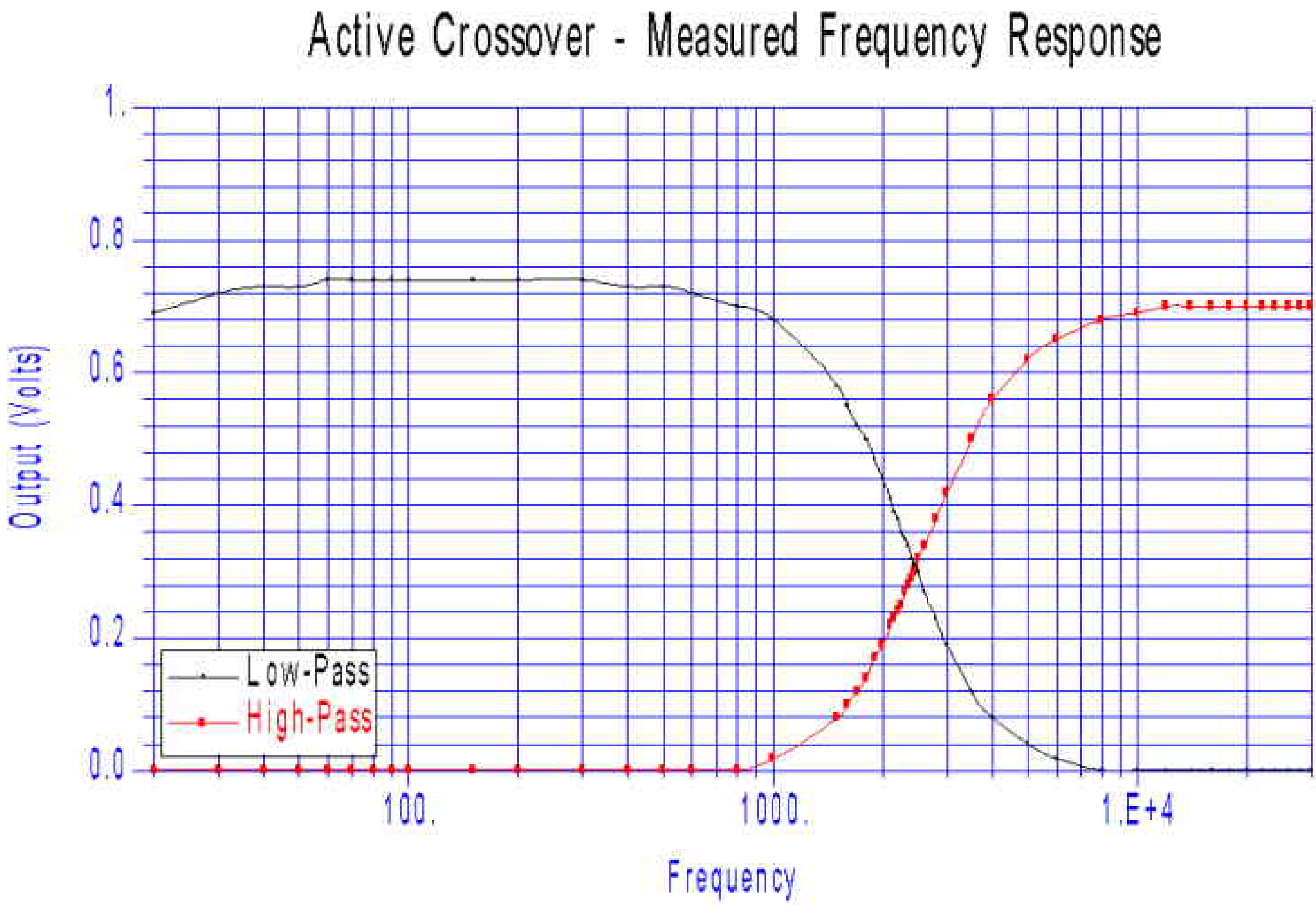


Simulation result, 12AX7. [Click here for a more readable version (83kB PDF file)]

Note that there isn't much difference between the two, but one thing I did on the 12AX7 circuit was to pre-compensate the gains so that they matched between the low-pass and high-pass sections. The 12AX7 cathode follower has a much higher output impedance, so to get this match I had to muck around adding some resistors to get the gains to match. In the 12AU7 circuit, I did no matching. You can see in the response curves that the 12AU7 high-pass output is slightly lower than the low-pass... the 12AX7 (before compensating for the Zout) was a good 3dB down on the high-pass side, where the 12AU7 is about 1dB. For these reasons, I decided to use 12AU7 tubes for this (actually I used GE 5814's). I'm sure 6922's or other tubes with medium mu and reasonably low Rp would work well also.

Note that in both cases the phase response is smooth, and equal at the crossover frequency. Note that you really don't care about the phase of the low-pass output far above crossover, nor the phase of the high-pass far below crossover; there will be no signal getting through the crossover at those frequencies. So the overall phase shift will be close to 0 at low frequencies, about 180 degrees at the crossover frequency, and a max of 270 degrees at the highest frequency.

The measured response of the crossover (using 12AU7 tubes) was very close to the simulation result, as shown below. The "bumps" on the plot are probably as much a matter of my measurement accuracy as anything - I took these numbers by hand and plotted them. I didn't measure the phase response, but have no reason to expect that it would be much different from the simulation either.



Measured frequency response

Setting the crossover frequency

As I mentioned, the crossover frequency is set by the resistor and capacitor values in the filter. For a 4-pole linkwitz filter, the first stage (2 poles) and the second stage (2 poles) are identical, making things much simpler. If you want to implement another filter type, read up (the two references above are great) to decide how to determine the part values.

The method used to pick the component values here is as follows:

1. Somewhat arbitrarily select the capacitor value C. I say "somewhat" arbitrarily, because the value of C affects the corresponding values of R needed, and you want to keep both in a range that is practical. If you pick a really small C you will wind up with resistors in the megohm range, the circuit may not work well do to the finite constraints on things like the tube input impedance, and leakage currents. You may also not be able to find the right part value as a "real" component.

For this design, I picked a C value of 0.001uF, or 1000pF. This value is pretty good for most 2-way crossovers. You may need to increase this to a larger value, like 0.01uF or 0.1uF if you need a very low crossover frequency (like for a subwoofer).

I just paralleled two capacitors of value C to get the capacitor of value 2C.

2. Calculate the value of resistor R (in ohms) by the following formula: R = 1 / (2*pi*1.414*f*C), where f is the desired crossover frequency in Hz, and C is the value of C in farads. This is the same as 1 / (8.886 * f * C).

Using my 2300Hz as an example and 0.001uF value for C, the R = 1 / (2*3.1416*1.414*2300*1x10e-9), or 48,937 ohms. The closest 1% resistor value to this is 48.7k ohms. 2R is 97,875 ohms, so 97.6k is the closest available. These are the values that I used in the simulations and measurements above.

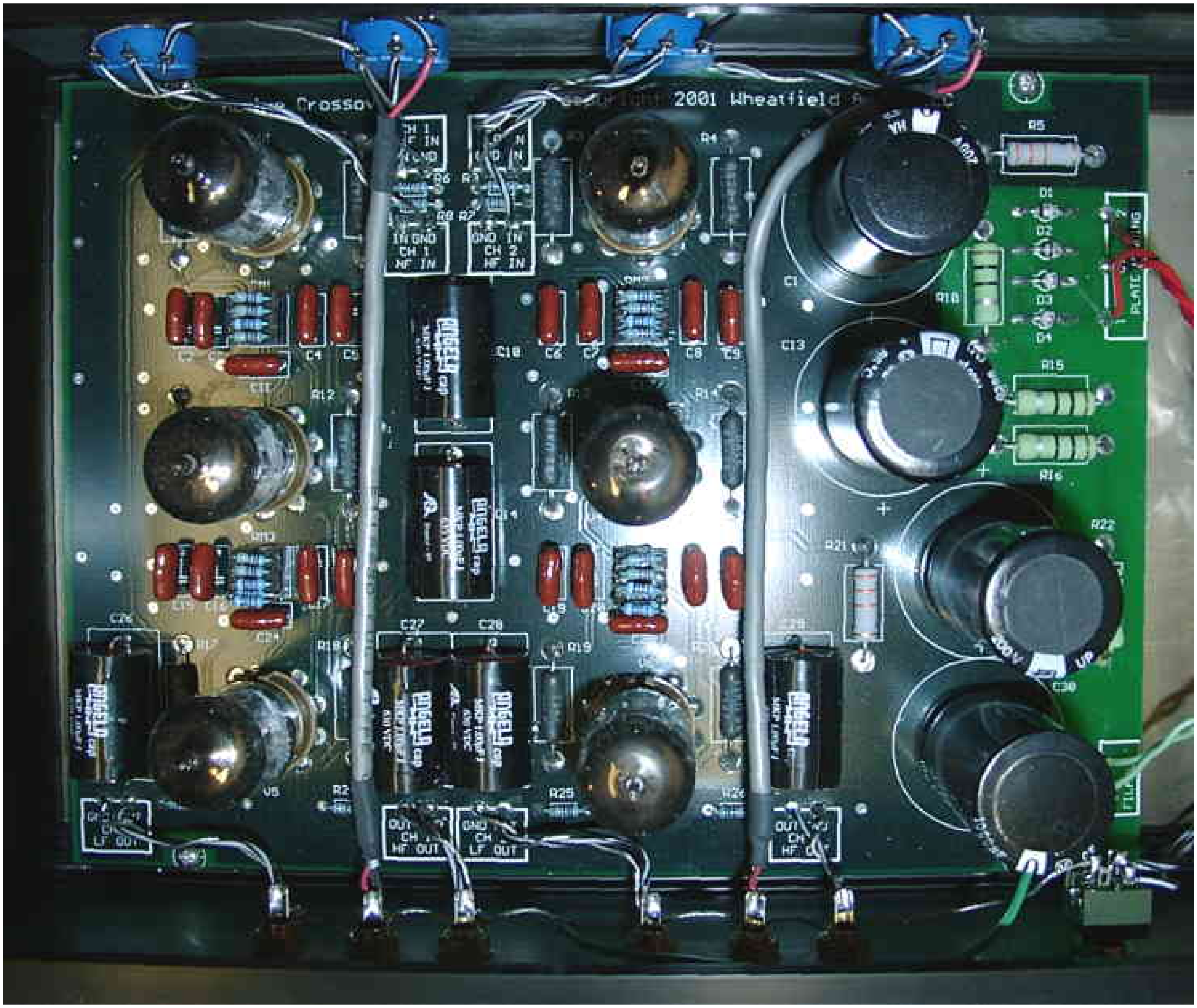
The error caused by going to the nearest 1% resistor is negligible, but I would not use 5% or 10% resistors if you can avoid it. The capacitors really should be 1% as well, but 1% tolerance caps can be hard to find. I measured a batch of 20 0.001uF 10% polypropylene capacitors, and found that all but 4 measured within 1%. The ones that didn't were all within %&. except one was off by around 3%. You might be able to get some of the audiophile parts vendors to select caps for you, or if you can get your hands on an RCL bridge, you could measure them yourself... but odds are pretty good that even if you use 5% caps you won't see any noticeable problem.

You can also take the values I have above and just scale them linearly with frequency. The resistors get bigger for lower frequencies; i.e., the resistance in *inversely* proportional to the frequency. If you wanted a 4600Hz crossover (2 times 2300Hz) you would use resistors of 1/2 the value I did; similarly, for a frequency of 1150Hz (half 2300Hz) you would use resistors of twice the value I did. You can see from this if you want to go to a real low frequency, you may need to make the caps bigger. For example, at 100Hz using C=.001uF, R has to be 1.125M. This is probably too big, and will introduce errors. You'd be better off with a cap 10x as big (0.1uF) and a resistor 1/10 as big (11.25k).

More Pictures

Front Panel

Rear Panel



Detailed view of PCB in chassis

Notes on building your own crossover

As I mentioned above, the only technical area that I wasn't completely happy with in this prototype was it's noise performance. Part of the problem may have been that I got lazy and grounded all of the RCA jacks to the panel. If you build this, I would recommend using isolated RCA jacks.

You may also want to consider using a bigger chassis, and/or putting the power supply in a separate enclosure. There is definitely some coupling from the power transformer - it was much worse with an EI transformer, that's why you see a toroid in the picture. Also note that there is no connection between the filament winding and ground on the PCB. You will need to make this connection somewhere - I found that there was a large amount of noise induced if I let the filaments float. You might even want to consider DC filaments here to keep the noise down.

Total power required is +/-100V at about 120mA, and 6.3V at 1.8A (for 12AU7's). A Hammond 261G6 works fine for this, providing 250VCT at 144mA and 6.3V at 2A; but as I said above, you will need to move it farther away from the PCB than is possible in this enclosure. Note that there is virtually no DC current drawn from ground, so you can actually just use an isolated 200V supply, and let the bleeder resistors split ground. The toroid transformer I used has no center tap, so essentially this is the way I'm running it.

I used an enclosure from Sescom (model MC-25A) to house the crossover. You will find that the holes in my PCB don't exactly line up with the mounting in the enclosure, so if you edit the PCB you might want to check this out (I

think they are 0.05" too close together, maybe more). Oops.

The PCB does not have any gain adjust controls on it. In fact, the PCB is laid out as four separate filters, two high-pass and two low-pass. To make a normal stereo crossover, you need to connect the input of a high-pass and a low-pass section together, to form the input. You can place a potentiometer at either the input or the output of the filter to adjust the gain. Putting it at the input is best for distortion (the input is attenuated first), the output best for noise (noise gets attenuated with the signal). I put the pots on the input.

PCB and design file downloads

If you have Eagle CAD, you can download the Eagle CAD schematic and PCB files, as well as the Gerber files (170kB ZIP archive) to modify or to fab a board. You have my permission to use these for non-commercial use as you see fit. See the commercial use notice above if you want to try and make a product out of it. If you modify them please remove the copyright statement.

Understanding and Operating Your Crystal Radio

Your crystal radio receiver is designed to tune stations on the AM broadcast band (radio frequencies of 540 to 1610 kHz). You will be limited in the number of stations you can hear when operating the radio without amplification. Keep in mind that a crystal radio operates ONLY on the power received from the radio station transmitter. Therefore, your ability to hear a station will depend to a great extent on the distance from the radio transmitter to your house and the amount of power the station uses to broadcast their signal. Another important factor will be the antenna you use with your radio.

Most of our club members live in Geauga County. As far as I know, there is no radio station broadcasting on the AM band in our county (at least not a powerful station). From my home in Chesterland, the strongest station tuned on my crystal radio is WTAM. This station broadcasts with 50,000 watts of power on a frequency of 1100 kHz. The radio transmitter is located at 8200 Snowville Road, Brecksville, Ohio. The distance from the transmitter to Chesterland is about 23 miles (21 miles to Auburn Twp and 31 miles to Chardon). Figure 1 is an aerial view of the WTAM transmitting antenna, which is 480 feet tall.

Figure 1 WTAM transmitting antenna

As radio waves travel away from the transmitter, the power density of the radio energy varies inversely with the square of the distance. What does that mean? We can write this as a proportion:

$$power\ density\ \propto \frac{1}{distance^2}$$

Let me give some examples. The power density of a radio wave at a distance of 10 miles from the transmitter is:

$$power\ density\ \propto \frac{1}{10\ \times\ 10} = \frac{1}{100} = 0.01$$

The power density at 20 miles is:

$$power\ density\ \propto \frac{1}{20\ \times 20}\ = \frac{1}{400}\ = 0.0025$$

Therefore, the power density at 20 miles is 1/4th the power density at a distance of 10 miles. At a distance of 40 miles, the power density will be 1/16th the power density at 10 miles. All other things being equal, if your crystal radio is located 40 miles from the transmitter, the signal strength delivered to the radio will be 1/16th what it would be if located 10 miles from the transmitter. This is why you will have a better chance of hearing a station, the closer you are to its transmitter. Of course the amount of power used in transmitting makes a difference. If two stations are the same distance away, but one transmits with 1,000 watts of power and another transmits with 50,000 watts, the 50,000 watt station will be considerably louder than the one with 1,000 watts.

Antenna for the Crystal Radio

The antenna you connect to your crystal radio will determine to a great extent the number of stations you can hear. It is doubtful that an indoor antenna will be sufficient unless you live within a few miles of an AM radio transmitter. Provided that you have permission from your parents, you can install an outdoor antenna. You should ask your parents for assistance in erecting the antenna. This can be a temporary antenna, put up only when you are using the radio, or a more permanent installation. Again, you should ask your parents which kind of installation they will allow. Some people think that antennas are not attractive and you must keep this in mind.

The antenna that I use for my crystal radio is of the long wire type (14 gauge, stranded and insulated). It is permanently installed. I drilled a hole through the window frame to allow the antenna wire to exit from the GEAR workshop to the outside. I installed a hook on the edge of the roof and with an insulator, attached the wire antenna. The wire length from window to the edge of the roof is 11 feet. Then the wire runs to a tree 50 feet from the roof. The attachment to the tree is 18 feet above the ground. The wire then runs to another tree 61 feet from the first tree and also 18 feet above the ground. At the second tree the wire goes through a pulley and then down to the ground where it is attached to a weight. The total length of the antenna wire, from the window to the end is 140 feet (you will also need additional length inside the house to reach the radio). The pulley is used as part of the antenna tensioning system. When the wind moves the tree branches, the wire moves through the pulley to prevent breakage of the wire. The weight at the end of the wire provides the tensioning of the antenna so that it does not dip excessively toward the ground between its supports. This antenna works well and I can hear four or five stations during the day.

When you work 18 feet above the ground, there is danger of a serious or fatal injury from a fall. If you want to erect an antenna like the one I have described, **DO NOT ATTEMPT THIS ON YOUR OWN. PLEASE HAVE YOUR PARENTS HELP YOU**. I used a ladder to attach the antenna wire to the trees. This kind of work can be very dangerous and you must use proper safety procedures. The job takes a minimum of two people, one to hold the ladder while the other person climbs the ladder. The ladder should be secured with ropes so that it will not slip off the tree. It is also a good idea to use a safety harness that connects the climber to the ladder in case they slip on a ladder rung.

A safer procedure, although possibly more frustrating, is to throw a light line over a tree branch from the ground. Attach a weight to the end of a string and attempt to throw the weight over a branch. If that does not work you might try using a slingshot. It would be a good idea to wear a hard hat or bicycle helmet while doing this in case the thrown weight comes back down on your head! If you have a very long pole, you might use that as well to hoist the wire over a branch. These methods are preferred over the ladder since they are safer. After you are successful in getting a string line over a tree branch, connect the string to your antenna wire and pull the string to hoist the antenna wire in place.

Ground Connection for the Crystal Radio

In addition to the antenna, a connection to ground is required. The ground connection is actually part of the antenna system. For the antenna I have described, I used a grounding rod, which you can find in the electrical department at a hardware store. The rod is 8 feet long and all but a few inches are driven into the ground with a sledge hammer. Make sure there are no pipes or underground electrical wires in the area where you install the grounding rod. It is best to install the rod near where the antenna wire exits

the house. The rod is copper-clad steel. A special bronze clamp is used to attach a ground wire to the rod. The other end of this ground wire is connected to the ground connection (black wire) of the antenna coil of the radio. The grounding rod must be in moist soil to work well. Of course it is difficult to know how moist your soil is 8 feet below the surface. But if your antenna does not seem to be working very well, you may need to water the soil around the grounding rod.

If you are not sure you will use your radio very much, you may decide to erect a shorter outdoor antenna. I erected a temporary long wire antenna, 11 feet from window to edge of roof, 50 feet to a tree branch that was 7 feet off the ground, then ran the wire to the ground and tied to a weight (total of 68 feet of wire from the window to the end of the wire). For this antenna I did not use a grounding rod. Instead, I connected the ground wire of the antenna coil to the ground system of the house electrical wiring. This can be done by connecting a wire to the screw of a faceplate for an electrical receptacle – see Figure 2 (**DO NOT PUSH THE WIRE INTO ONE OF THE RECEPTICLE SLOTS AS THIS COULD RESULT IN A FATAL ELECTRIC SHOCK**).

Figure 2 ground wire connected to faceplate

Using the shorter antenna and ground to faceplate, I could only hear station WTAM 1100. After you have completed the audio amplifier for your crystal radio, you will be able to hear more stations with the shorter antenna. However, if you have an interest in hearing distant stations, the longer antenna with grounding rod will be better.

When there is a chance of an electrical storm in your area, it is advisable to disconnect your antenna at a location outside your house. While lighting strikes on an antenna like yours are rare, it is better to be safe and prevent the very high current and voltage from entering your house. It is best if your exterior antenna is connected to ground outside the house when not in use.

Calibrating the Tuning Dial

The knob connected to the variable capacitor of the radio has a white pointing line to indicate the position of the variable capacitor. The position of the variable capacitor determines the radio frequency tuned (the station). However, the front face of the radio does not have any markings to indicate the frequencies for various positions of the knob. Mr. La Favre will help you mark the face of the radio at intervals of frequency. To do this we will use a signal generator. The signal generator will be connected to a coil that will substitute for the antenna coil. The signal generator can be adjusted to any radio frequency desired. In addition, the radio frequency can be modulated (AM - amplitude modulation) with an audio frequency, which you can hear as a tone in the radio earphone. We will start by adjusting the signal generator to a radio frequency of 600 kHz, modulated with an audio frequency of 400 Hz (400 Hz is a tone just a bit lower than the musical note A above middle C – that A is 440 Hz). The coil attached to the signal generator is placed next to the tuning coil of the radio. Then the tuning knob of the radio is adjusted until the 400 Hz tone is heard clearly in the radio earphone. The knob is adjusted to the position where the tone is heard with the highest volume. At that point a felt-tipped pen is used to place a mark on the front plate of the radio to match the position of the white line of the tuning knob. Then that line is labeled with the number 600 (600 kHz). We will continue by adjusting the signal generator in increments of 100 kHz, marking each knob position for each frequency. When finished, you

will have marks on the face of the radio for 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500 and 1600 kHz. These marks will be helpful in adjusting the variable capacitor to tune a specific station.

Functions of the Various Components of the Crystal Radio

The most important reason for completing the Crystal Radio project is to learn how a radio works. Of course I also hope you will enjoy using your radio. To begin, let us take a look at the schematic for the radio provided below.

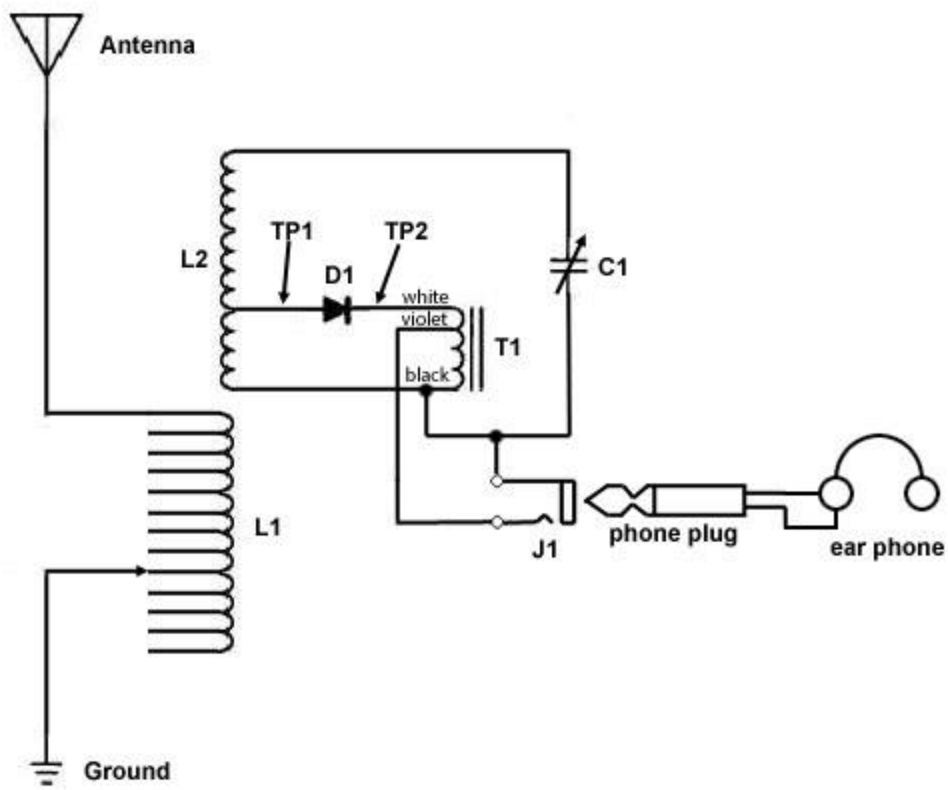


Figure 3 schematic of the Crystal Radio

L1 is the antenna coil and L2 is the tuning coil. The antenna coil has 12 taps. The ground wire is terminated with an alligator clip, which is used to connect to one of the taps. After tuning a specific station with the variable capacitor, C1, the ground wire is connected to the tap of coil L1 which gives the loudest signal as heard in the earphone. By selecting the best tap on coil L1, you are actually tuning the antenna to *resonate* at the tuned frequency. An antenna that is tuned to a specific radio frequency will deliver the strongest signal to the radio. When you adjust the variable capacitor to tune another station, you may need to adjust the tap connection on L1, especially if the new station tuned is of a significantly different frequency than the previously tuned station. Higher frequency stations will require connection to a tap closer to the antenna end of the coil. As you tune stations of lower frequency, you will need to adjust the tap connection to a tap further from the antenna end of the coil. In other words, a station of lower frequency will require the signal to travel through more coil turns than one of higher frequency. The exact tap to use will also depend on the length of your antenna.

Therefore, it is not possible for me to tell you which tap to use for a specific station. You will need to establish this by trial and error. If you are not able to find a tap on the coil that provides a stronger signal than other taps, then it is likely that your antenna is too short to tune to resonance. Nevertheless, this will not prevent you from hearing stronger stations.

Figure 4 below is a photo of the assembled radio. The green wire labeled A is the antenna wire and the black wire labeled B is the ground wire which connects to the grounding rod just outside the window of the GEAR workshop. D is the antenna coil (L1 in schematic). C is the alligator clip, attached to one of the taps of the coil. The red wire of the antenna coil connects to the antenna wire and the black wire connects to the ground wire. After making these connections, and placing the antenna coil (D) near the tuning coil (E), your radio is ready for use.

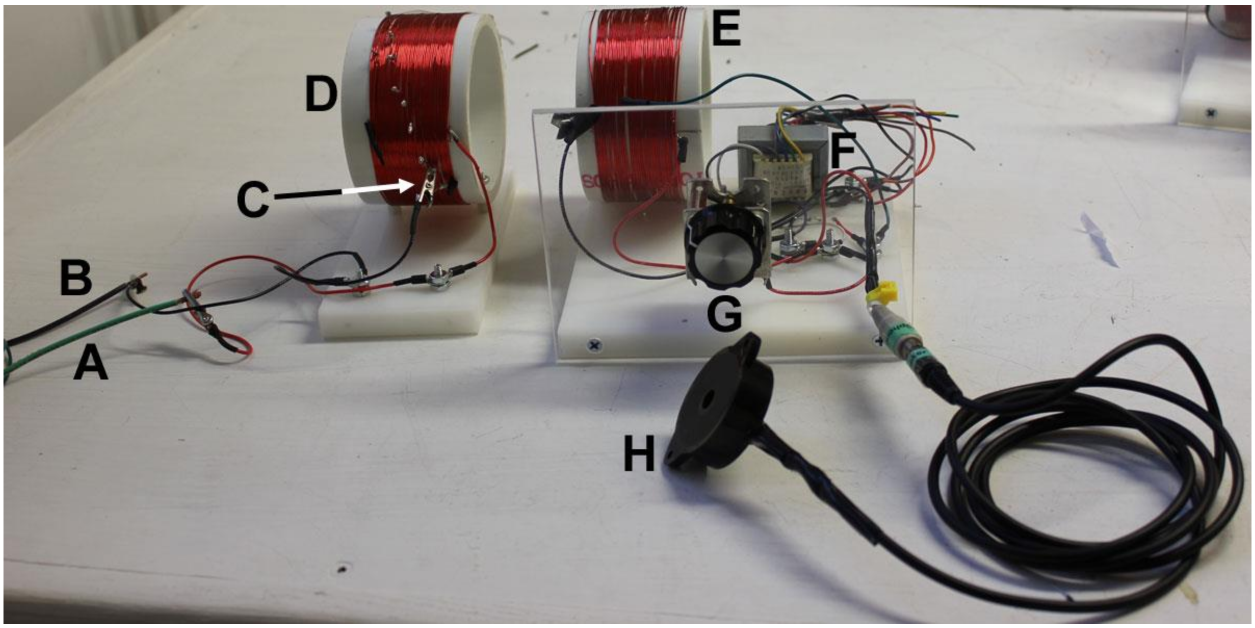


Figure 4 assembled crystal radio

F is the audio transformer, which is labeled as T1 in the schematic of Figure 3. The audio transformer is used to match the impedance of the earphone (H). G is the knob attached to the variable capacitor.

The radio signal present in the antenna coil (D) is transferred to the tuning coil (E) by the magnetic field generated by the antenna coil. When current flows through a coil, a magnetic field develops around the coil. If another coil is placed near that coil, then the second coil is also immersed in the magnetic field created by the first coil. This is the means for transferring the radio signal from the antenna coil to the tuning coil.

The transfer of the signal between the coils can only occur if the current flowing in the antenna coil is alternating current. As it happens, the current established in the antenna coil is alternating current. When an antenna captures radio waves, the radio waves are converted to an alternating current in the antenna circuit, which includes the antenna coil. As the current flows back and forth through the antenna coil, the magnetic field builds and then collapses around the antenna coil. It is the changing magnetic field which is required to transfer the electrical energy from the antenna coil to the tuning coil.

If the current flowing in the antenna coil was a constant direct current, there would be no transfer of electrical energy to the tuning coil.

The antenna coil and tuning coil together constitute a type of transformer. Transformers play important roles in electrical systems. The usual function of a transformer is conversion of voltage from one level to another. There is a transformer mounted to the electric pole near our house. It converts the high voltage (several thousand volts) of the electric line down to 240/120 volts for service to our house. In the case of our radio, we are not so much interested in converting the voltage of the signal in our antenna circuit as just transferring that signal to the tuning coil. We could just use one coil and connect the antenna, ground and variable capacitor to that coil. However, better results are obtained by using separate coils to tune the antenna and then transfer that tuned signal to the tuning coil via a magnetic field.

The antenna coil and tuning coil are mounted on separate bases so that you can adjust the distance between the coils. There will be a specific distance between the coils that results in the strongest signal received in the tuning coil and this may vary with the radio frequency tuned. The optimum spacing is not necessarily the closest spacing. As part of the process of tuning a station, you should adjust the space between the coils for maximum loudness heard in the earphone. In any case, the distance between the coils for best transfer of signal will be similar to that seen in Figure 4. For example, if you place the coils 12 inches apart, there will be little signal transfer.

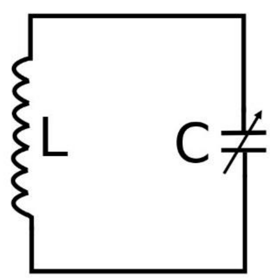


Figure 5 simple LC circuit with coil and variable capacitor

The variable capacitor C1 works together with the tuning coil (L2 schematic or E in photo) to tune a specific radio frequency. The tuning coil has a fixed amount of *inductance* and it is the adjustment in *capacitance* of C1 that allows tuning of different frequencies. Figure 5 shows a simplified version of the LC circuit of the crystal radio. The actual circuit for our radio contains a tap on the coil for diode D1 as well as other connections. But let us concentrate only on the coil L and capacitor C. In a certain respect the circuit of Figure 5 is an open circuit because current cannot pass through capacitor C. To be more precise, the circuit is open as far as direct current is concerned. However, we can consider the circuit closed in respect of alternating current. Capacitors behave in a fashion that allows current to flow temporarily in a circuit as the capacitor charges. With alternating current, the current flows for a short period only in one direction, especially at radio frequency rates of alternating current. As the current charges the capacitor, current is allowed to flow in the circuit. Once the capacitor is fully charged, current will no longer flow. What we must keep in mind is that at radio frequencies, current flows in one direction for a very short period of time. Let us take a frequency of 1000 kHz as an example, a frequency in the middle of the AM broadcast band. That frequency is equivalent to 1,000,000 cycles per second. Each cycle results in current flow in one direction followed by current flow in the opposite direction. The duration of flow in one direction is only 1/2,000,000th of a second or 0.5 microseconds. A microsecond is one millionth of a second. That is a very short amount of time. Even so, the electric current in the circuit in Figure 5 could travel around the circuit in much less time than 0.5 microseconds IF we did not include the capacitor and inductor (coil).

In order to tune the circuit for resonance at a specific radio frequency, we want the capacitor to charge and discharge at a rate that equals the frequency. If we removed the inductor (L) from the circuit, the

capacitor would charge and discharge much faster than the rate required for tuning the circuit to resonance. By including the inductor, we slow down the rate of current flow, which in turn results in a slower charge and discharge of the capacitor. It is the interesting behavior of an inductor (coil) that we have employed to establish resonance. When voltage is first applied across an inductor, very little current is allowed to flow through the coil. Instead, a magnetic field starts to build around the coil. As time wears on (here we are talking about very little time), more current is allowed to flow through the inductor. The degree of hindrance in current flow by an inductor depends on the amount of inductance of the coil. We measure this in units named Henries, just as capacitance of a capacitor in measured in units of the Farad. An LC circuit containing a coil of a specific value of inductance and a capacitor of a specific value of capacitance will be resonant at a specific radio frequency.

Resonance can be a difficult thing to understand. Let us take the analogy of a child on a swing. As the child swings back and forth, the parent gives a push just as the backward movement stops. The end result of these timed pushes is that the child continues to swing. The swinging of the child is in resonance with the pushes given by the parent and the child will continue to swing indefinitely. Now suppose that the parent delivered the pushes while the child was still moving backward. In this case, with each cycle of the swinging back and forth, the amount of the swing will diminish until it ceases. In this case there is not resonance of the swinging and pushes.

The LC circuit is much the same. At a specific radio frequency, the frequency of resonance, the current flows back and forth in the circuit, timed exactly to match the rate of capacitor charging and discharging (the capacitor is somewhat like the parent pushing). At frequencies other than the resonance frequency, the current flowing back and forth in the circuit does not match the charging and discharging rate of the capacitor. Thus, the electrical energies of the non-resonant frequencies are absorbed in the LC circuit and not passed on to the remaining circuits of the radio. It is by this method that a signal of a specific frequency is allowed to pass through the radio while other frequency are not. If this did not happen, then we would be hearing many radio stations at one time.

Two important characteristics of a radio are **sensitivity** and **selectivity**. Sensitivity is the ability of a radio to deliver a sound that you can hear, derived from a weak radio signal received. Radios other than the crystal type include some type of signal amplification so that stations with weak signals can be heard. Sensitivity can be measured as the minimum signal voltage received that results in audible sound. Crystal radios have poor sensitivity because they rely only on the power received from the tuned radio waves. The efficiency of the radio antenna in capturing energy from the passing radio waves affects the signal strength received by the radio. Since crystal radios do not amplify the signal, it is especially important to use efficient antennas with crystal radios.

Crystal radios are also known in general for poor selectivity, although better designs have better selectivity. It is not uncommon for more than one station to be heard at a particular setting of the variable capacitor due to poor selectivity in the crystal radio. Nevertheless, you will be able to find some stations that you can hear clearly without interference from another station. It just depends on the separation in frequencies of the strong radio stations received at your location. More advanced radios, of the kind you are familiar with, have much better selectivity and usually tune only one station at a time, even when strong stations have frequencies very close to each other. I will not detail the reasons for this any further at this point as the improvements in selectivity require a discussion of circuits not found in crystal radios.

Figure 6 is a portion of the radio schematic showing part of the tuning coil, the detector diode D1 and the audio transformer T1. Two test points are marked on the schematic. We will connect an oscilloscope to these test points so that we can visualize the radio signal at these points in the radio. This will help in understanding the radio.

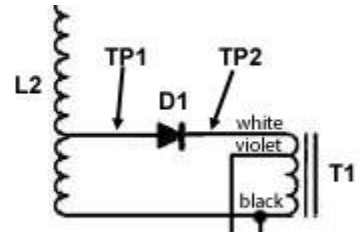


Figure 6 detector schematic of radio

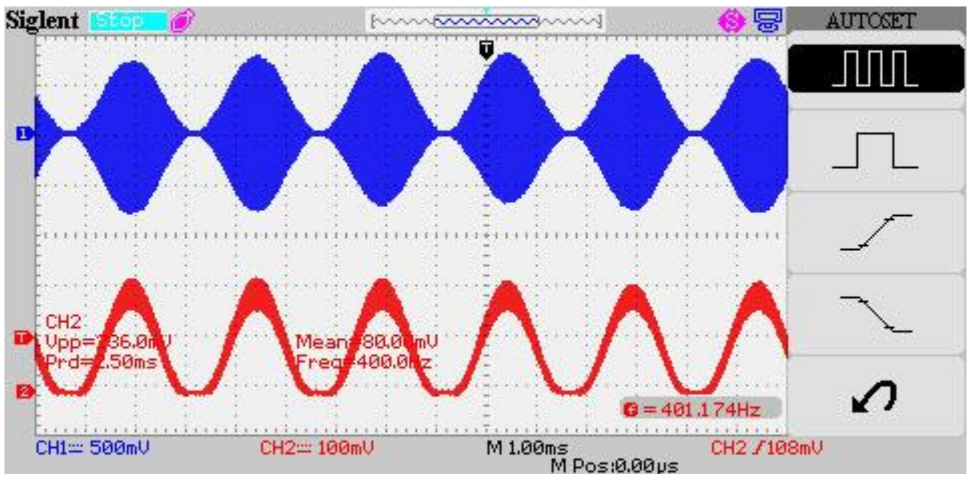


Figure 7 oscilloscope traces at test point 1 (blue) and test point 2 (red)

An oscilloscope is an instrument that can be used to visualize rapidly changing electric signals. Figure 7 is the oscilloscope traces at test points one and two (see Figure 6 for locations of test points). A signal generator is connected to the radio providing a radio frequency of 1100 kHz, modulated by an audio frequency of 400 Hz. The blue trace displays the radio frequency at test point one modulated by the audio frequency. In the trace you can only see the waves of the audio signal. The waves of the radio frequency are so numerous that they appear as a solid blue color. It would be necessary to stretch the display to a great extent in the horizontal direction before we could see the individual radio frequency waves in the blue colored trace.

The height of the blue radio waves is *modulated* by the audio signal (amplitude modulation or AM). The audio signal is much lower in frequency than the radio frequency (the number of audio modulations are much fewer than the number of radio frequency waves). Notice the blue tab labeled “1” on the left side of the blue trace. That tab marks the position of 0 volts. Any time the wave is above the tab, the voltage will be greater than 0. Any time the wave is below the tab, the voltage will be below 0 (a negative voltage). The radio frequency must have alternating positive and negative voltage in order to force periodic reversal in the direction of current flow (like quickly switching the connections to a battery). Otherwise, the current would not change directions and it would not be alternating current.

You should notice that the red trace, representing the signal at test point two, looks very different. Test point two is on the opposite side of the detector diode from test point one. Also note that for this test the diode connection to the transformer T1 was disconnected. Since the diode blocks current flow in one direction, we should not expect to see positions of negative and positive voltage on the wave trace here. In fact, notice where the 0 volt red tab with the label “2” is located. The bottoms of the red waves are at 0 volts. All positions of the waves are at 0 volts or higher because the diode has rectified the radio signal. We call this *detection*. The diode has converted the alternating current radio signal into a

pulsating direct current audio signal. It is the audio signal that we need to apply to the earphone in order to hear the sound. If we were to just apply the radio frequency itself to the earphone we could not hear any sound. Humans are not capable of hearing sound at a frequency higher than 20,000 Hz.

After passing through the detector diode D1, the extracted audio signal passes through the audio transformer. The transformer transfers the audio signal to the earphone where the electric signal is converted into sound waves that you can hear. The transformer performs an important function in matching the *impedance* requirement of the tuning circuit to the impedance requirement of the device used to convert the electric signal to sound. The transformer has many taps that represent different impedances. The tuning circuit is attached to the white and black wires of the transformer, which provide about 40,000 ohms of impedance. The earphone is attached to the violet and black wires of the transformer, which provides 10,000 ohms of impedance. This is the best impedance matching I have found by listening to the signal in the earphone and selecting the loudest sound produced when testing all possible connections on the transformer. If you happen to have another high impedance earphone or headset you would like to use with your radio, you may need to use another tap on the audio transformer to connect to the device. The black wire should always be used as one connection. The gray wire provides 20,000 ohms, the blue wire 5,000 ohms, the green wire 2,500 ohms, the yellow wire 1,200 ohms, the orange wire 600 ohms and the red wire 300 ohms. I happen to have a very old pair of high impedance headphones from about 1920 that are designed for crystal radios. It works well when connected to the yellow wire of 1,200 ohms impedance. Modern headsets and earbuds are mostly low impedance devices that will not work with the crystal radio. However, if you pass the signal through the amplifier you will build (which has a high impedance input and low impedance output), then you can use your modern headphones to listen to your crystal radio. The amplifier works well using the 10,000 ohm violet wire connection to the transformer, the same as the earphone supplied with the radio kit.

Impedance is a measure of the resistance to alternating current that a device presents to a connected signal. It is not the exact same thing as a pure resistance, which we can call ohmic resistance. Impedance also accounts for something called *reactance*. Inductors (coils) have reactance, a kind of resistance to current flow as already mentioned. Impedance is a measure of resistance that accounts for the combined effects of ohmic resistance (like a resistor) and reactance (like a coil). In fact, the speakers that are used in radios that you typically use employ a voice coil attached to a diaphragm to convert an electrical signal to sound. The long length of wire used in the coil presents some ohmic resistance to current flow. Since the wire is wound into a coil, it also presents some reactance to current flow. Both of these are combined into a measure of resistance known as impedance. Typical speakers have impedances of 4 or 8 ohms and require much too much power to work with a crystal radio.

Keeping a Log for Your Radio Listening

Most people listen to radio for the programming content. However, if you are serious about radio technology, you may wish to maintain a log of your listening. It can be fun to see how many stations you can hear with your radio. The conditions for propagation of radio waves varies over time and it is probable that you will hear some stations at certain times and not at other times. Therefore, you should listen at different times of the day and night. By keeping a log, recording the stations you can hear, and the date and time, you will create a log of your listening. From this log you may discover some interesting trends. For example, some stations can be heard at night but not during the day.

Even though your radio is calibrated, you cannot know for sure the exact frequency for a station until you hear an announcement of the frequency by the radio announcer. Some stations announce this many times each hour and some do not announce their broadcast frequency very often. So it may be an exercise in patience on your part. The strong station in Cleveland, WTAM, broadcasts on 1100 kHz and announces their broadcast frequency several times per hour. The announcement may sound something like this: “This is WTAM eleven hundred.” You may need to listen carefully to catch the announcement because it is usually done fairly fast. Don’t expect to hear something like this: “This is station WTAM broadcasting on a frequency of eleven hundred kilohertz.” You might have heard something like that 50 years ago but not today!

There are some amateur radio operators (Ham Radio) that have become big fans of the crystal radio. They have studied the construction of crystal radios and compete with each other to design radios capable of tuning stations from distant locations. In fact, one Ham Radio operator located in Hawaii was able to tune a station in Cuba with his special crystal radio. In the case of the radio you have constructed, we cannot expect that level of performance. In fact, if you hope to hear distant stations with your crystal radio, you will probably need to use an amplifier. After you finish your crystal radio you will build an amplifier to use with your radio. Then you will be able to tune many more local AM stations and also distant stations at night if you have a good antenna.

There are different modes of radio wave propagation that determine which radio stations you can hear and at what time of day or night. This also varies with the frequency of the radio signal. For long distance reception, frequencies above those of the AM broadcast band are more useful. These frequencies, between 2 to 30 MHz, are sometimes referred to as shortwave radio or high frequency (HF) radio. Some of the Ham Radio bands are included in this range. International radio stations also broadcast in this frequency range.

Radio wave propagation can be divided into two broad types called ground waves and sky waves. Ground waves travel close to the surface of the Earth and sky waves bounce off the Earth’s upper atmosphere (ionosphere), which allows propagation to more distant locations. The bouncing of radio waves off the ionosphere depends on the amount of ionization. The ionization is caused by high energy radiation (UV light) from the Sun. Therefore, there is more ionization in the upper atmosphere during the day than at night. That is why radio propagation varies between day and night. This subject is considerably more complex than my short description might suggest, but we will leave it at this point for now.

During the day radio wave propagation in the AM band is generally confined to the ground wave type. Ground waves don’t travel much farther than the horizon. The distance to the horizon depends on the height of the radio transmitting antenna and its elevation above sea level. Nevertheless, propagation by ground wave is usually limited to 100 miles or less.

During the night the Sun does not shine on Earth’s upper atmosphere and the degree of ionization of air molecules and atoms decreases. With these changes, radio waves of the frequencies used in the AM band can bounce off the ionosphere. When this happens it becomes possible to tune in AM stations hundreds of miles from your location. Therefore, if you want to try tuning in distant stations, you will need to try this at night. The signal strength of these stations will be weak and you will have much better luck hearing these stations if you connect an amplifier to your crystal radio. In addition, it is especially important to use a good outdoor antenna if you are trying to tune in distant stations.

As you build a log of listening, you may wish to gather more technical information about the distant stations you have been able to hear. A good web site to consult is the FCC (Federal Communications Commission) site for AM stations: https://www.fcc.gov/encyclopedia/am-query-broadcast-station-search . The information at this site includes the location of the station's transmitter (given in longitude and latitude) and the amount of power used by the station. Some AM stations are required to broadcast with lower power at night in order to avoid interfering with other radio stations operating on the same frequency (due to longer transmission distances at night). The FCC licenses a limited number of "clear channel" stations in various locations in the United States. These stations are required to transmit with 50,000 watts of power day and night and these clear channel stations are the most likely ones you will be able to hear from distant locations. There is a list of clear channels at this web site: https://en.wikipedia.org/wiki/Clear-channel_station . Our strong AM station in Cleveland, WTAM 1100, is a clear channel.

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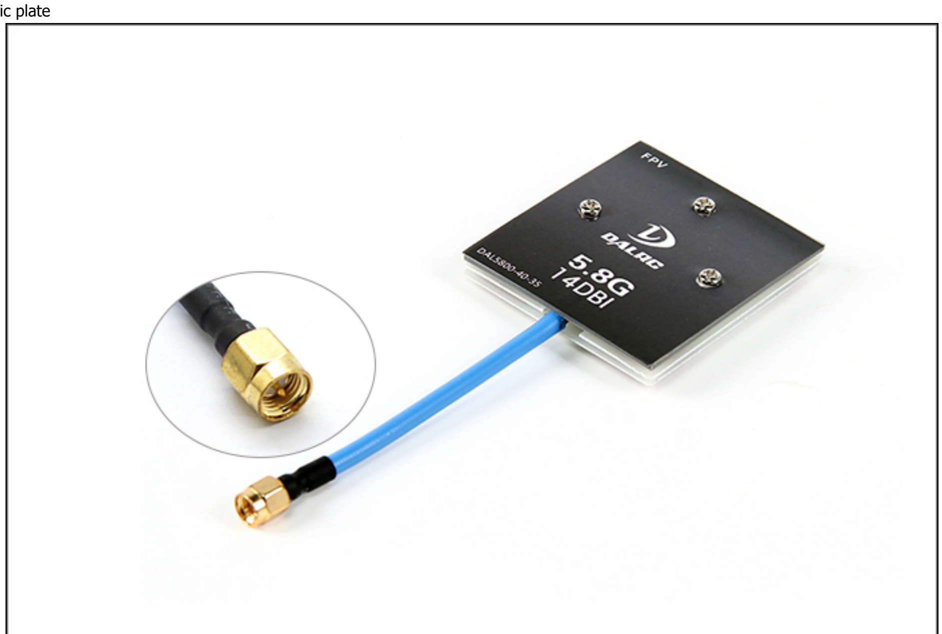
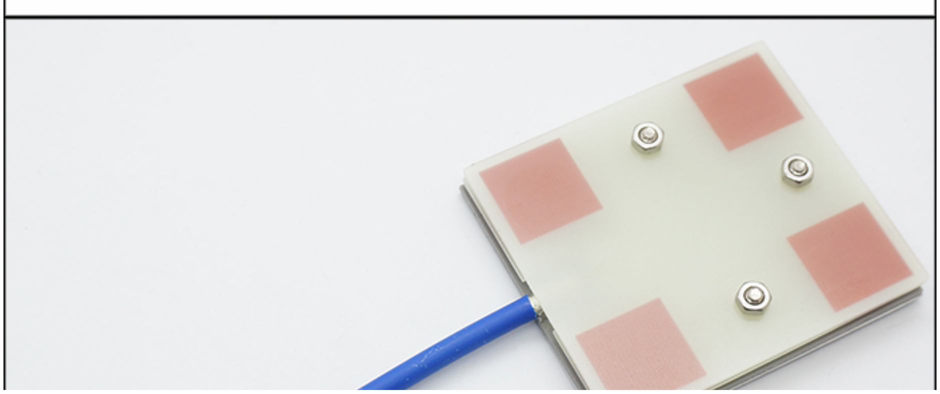
perating angle
e
2g)

:
45~5945MHz

ertical
Backward: ≤23dB
3dB Horizontal Beamwidth: 40°
3dB Vertical Beamwidth: 35°
First Side-lobe Suppresion: ≤13dB
Max Power: 50 watt
Resistance: 50 Ω
Lightning Protection: DC grounded
Connector: SMA/RP-SMA
Dimensions: 60x55x6mm
Weight: 32g
Material: Composite electromagnetic plate





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Topic 4.4.1 – Simple AM Receiver

Learning Objectives:

At the end of this topic you will be able to;

- ☑ draw a block diagram, and circuit diagram for a simple radio receiver, consisting of antenna, tuned circuit, detector/demodulator, and earphones;
- ☑ describe the function of each of these sub-systems;
- ☑ appreciate that a tuned circuit is a variable frequency band pass filter;
- ☑ design a tuned circuit to select a particular carrier frequency;
- ☑ select and use the equation $C = \frac{1}{4\pi^2 f_o^2 L}$ to calculate the value of C to provide a given resonant frequency.
- ☑ use the frequency response curves of a loaded tuned circuit to explain poor selectivity.

Module ET4 – Communication Systems

The Simple Radio Receiver

In section 4.3 we discussed a range of methods for linking an information signal with a high frequency carrier by means of a number of modulation techniques so that it can be transmitted. In this section we will explore some ways of retrieving the original signal so that it can be heard.

We will start with the simple radio receiver, which consists of five main functional blocks as shown below:

Antenna → Tuned Circuit → Detector → RF Filter → High Impedance Headphones

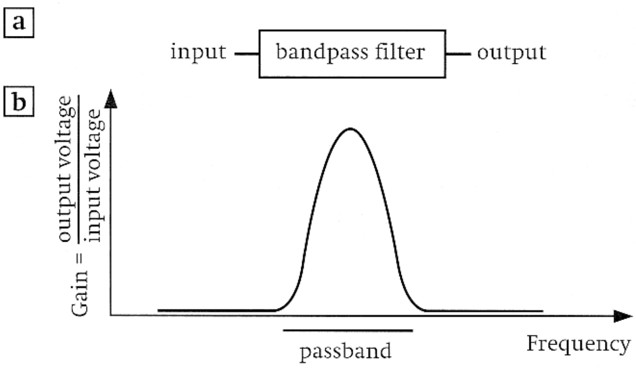
Every radio receiver requires an antenna (aerial) as the input, to convert the incoming radio waves into tiny alternating currents. Unlike the transmitting aerial which may only be transmitting one frequency from the radio station, the aerial will pick up all of the different radio broadcasts at different carrier frequencies within range. The actual current variation in the aerial will be a complex mixture of all these signals and so the first thing the receiver has to be designed to do is select one broadcast from among the many, and then extract its audio information.

The tuning circuit

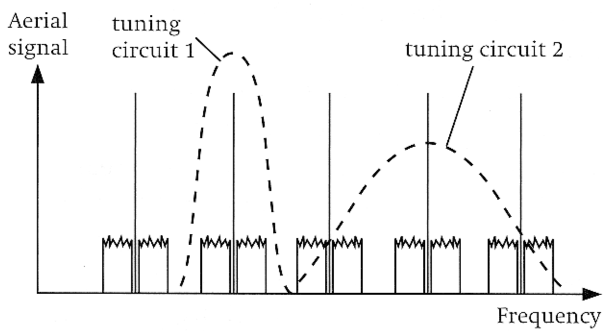
A tuning circuit is essentially a band pass filter (Topic 4.2.3) designed to pick up carrier frequencies typically in the range 300kHz to 3MHz. The frequency range (i.e. the frequency band it passes) can be **altered** by means of a **variable capacitor**. The frequency response of the tuning circuit is the gain as a function of frequency, where

$$\text{gain} = \frac{\text{output voltage}}{\text{input voltage}}$$

This is shown opposite (a) is the block diagram, (b) is the frequency response.



If this frequency response is now superimposed on the multi-carrier signal picked up by the aerial, then we have the graph shown below (where it is assumed that all transmissions are AM).



The frequency response curves for two types of tuning circuit are shown. Tuning circuit 1 has a pass band that has a high Q factor that just encompasses the carrier and sidebands, and so this tuner will be very selective, i.e. it will pick out just one station and reject the rest. Tuning circuit 2 has a much larger pass band and a lower Q-factor so is insufficiently selective; interference will occur between neighbouring transmissions.

The tuning circuit pass band is **centred** on the desired **carrier** frequency and the very small currents from this particular station are converted into very small voltages (typically μV or mV). Thus a very small copy of the original AM signal will be produced.

The detector

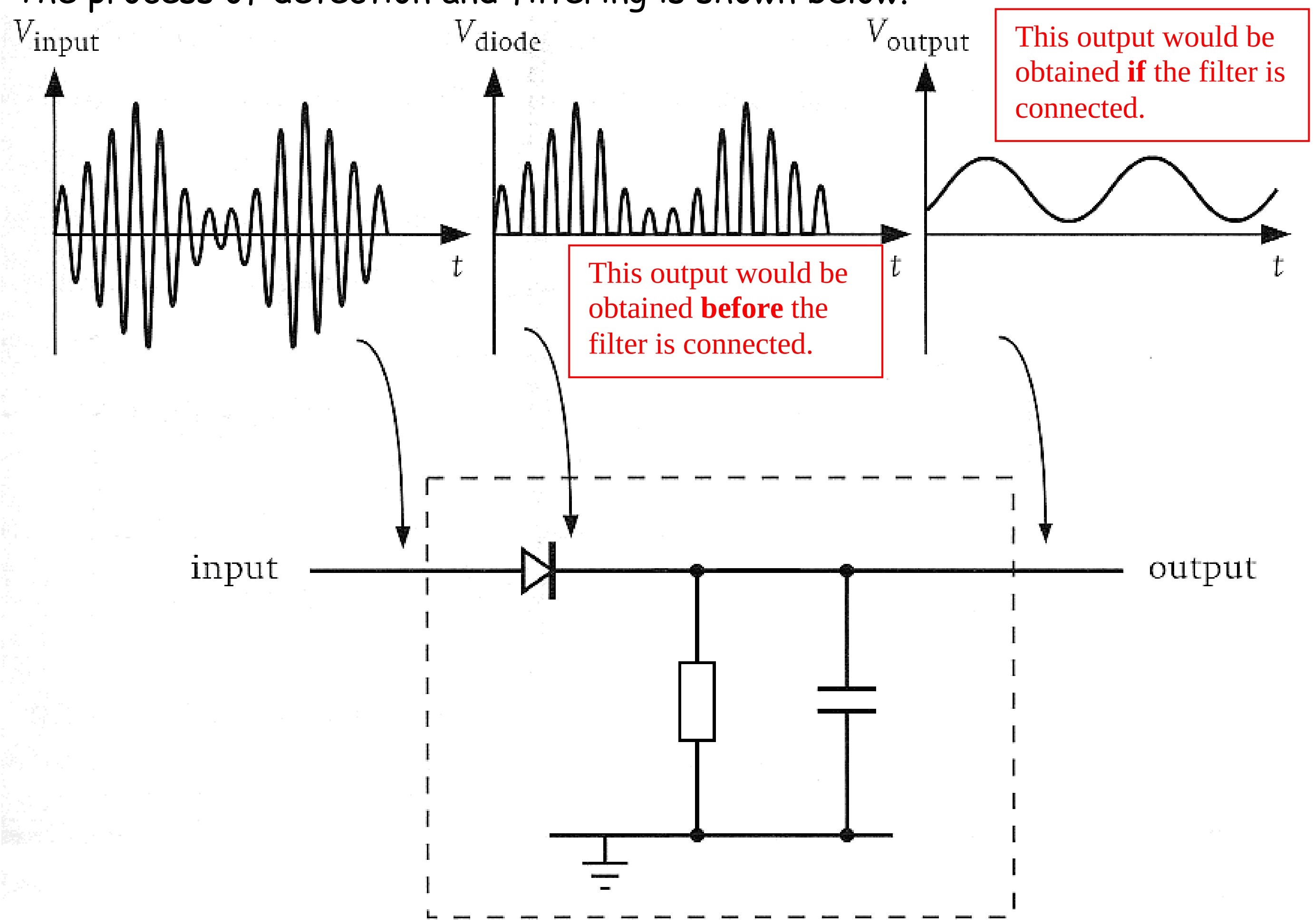
The function of the detector is to extract (i.e. detect) the audio signal. It does this by first rectifying the AM carrier with a diode circuit, so that the average value of the AM signal is no longer zero. As the received signals are very small, special diodes with a very low turn-on voltage are used for this purpose. They are usually made with germanium and have a turn-on voltage of approximately 0.2V instead of the 0.7V for a silicon diode. Even so, unless the received signal is **well above 200mV** then this simple radio receiver will not be able to receive it as the signal will not be able to turn-on the diode in the detector.

Module ET4 – Communication Systems

The RF filter

The half wave rectified pulses are then smoothed with a low pass filter, so that the remaining carrier frequency is lost and the slowly changing envelope (i.e. the audio signal) is obtained as output.

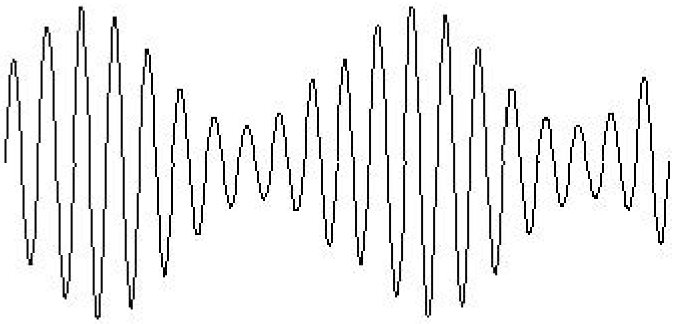
The process of detection and filtering is shown below.



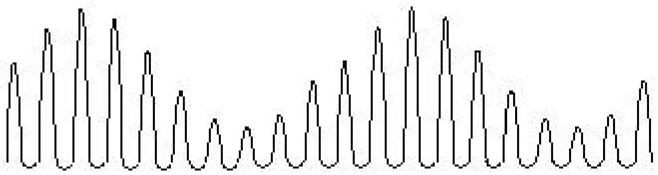
Note: a different type of low pass filter is used in the final stage as the type used in Topic 4.2.2. have a **series** resistor which would reduce the very small current in the radio receiver to an unacceptably low value. The good news however is that you don't have to know how this filter works just that it's break frequency is given by the same formula i.e.

$$f_b = \frac{1}{2\pi RC} .$$

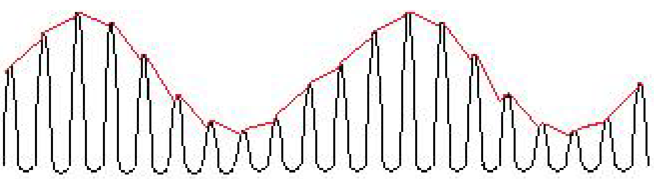
In practice the received signal would never be perfectly reproduced, the following diagrams show a more realistic output from the RF filter.



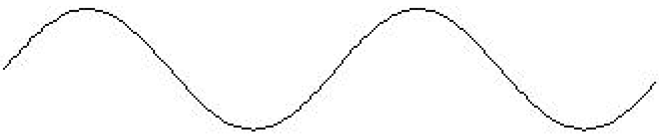
This is the amplitude modulated carrier.



This is the half wave rectified signal



The red line shows the attempt of the filter to reconstruct the original audio wave. The values of R and C used affect the quality of how smooth the peaks are joined.



The recovered audio frequency which is not perfectly smooth, and contains fluctuations.

The values of R and C need to be chosen carefully to produce:

- a break frequency just above the audio range of the information signal
- a time constant that is short compared with the period of the audio signal so the output follows the audio signal faithfully
- a time constant that is long compared with the period of the carrier so that C does not discharge appreciably and give a saw tooth effect superimposed on the audio signal
- a high impedance so that it does not draw a large current from the tuned circuit

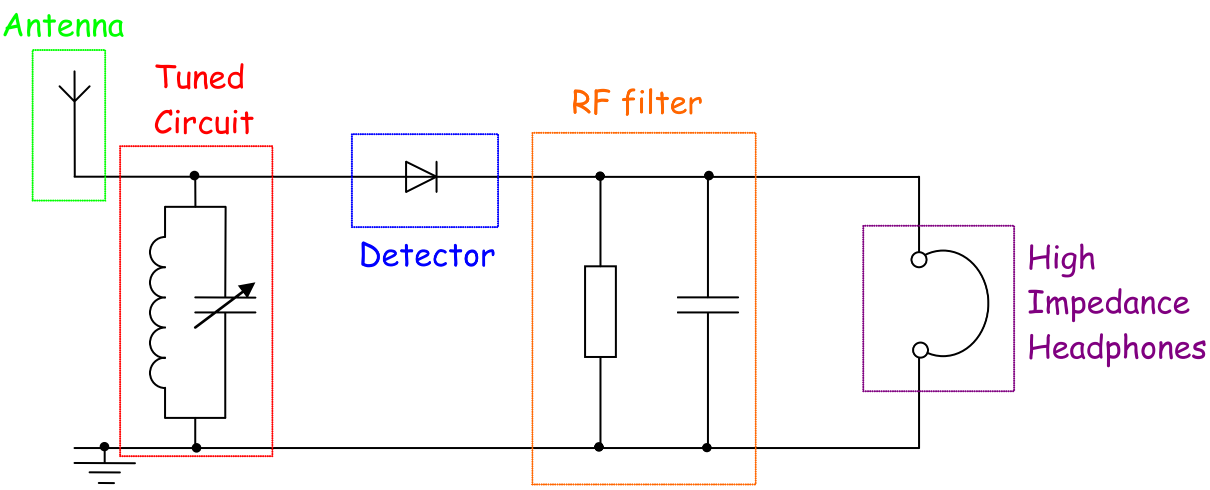
As a *rule of thumb* compromise, R is usually chosen to be greater than 50 kΩ along with a corresponding value of C in the range 20 to 1000pF.

The High Impedance Headphones

This is a transducer that converts the audio signal into small displacements of a diaphragm, so that the original audio information is recreated. The minor fluctuations in the audio signal tend to be ignored by most headphones. As this radio receives all of its power from the received radio signal it is unable to drive any output device other than very high impedance (~1MΩ) headphones .

Circuit diagram

The circuit diagram for a simple radio receiver is shown below.



Note : Sometimes the resistor in the RF filter is omitted from the circuit diagram because the internal impedance of the headphones is sufficient to work with the fixed capacitor to form the low pass filter. This circuit is powered only by the signal picked up by the antenna, no batteries or power supplies are needed. If you wanted to replace the headphones with a loudspeaker you would have to add an audio amplifier which would need a power source after the RF Filter.

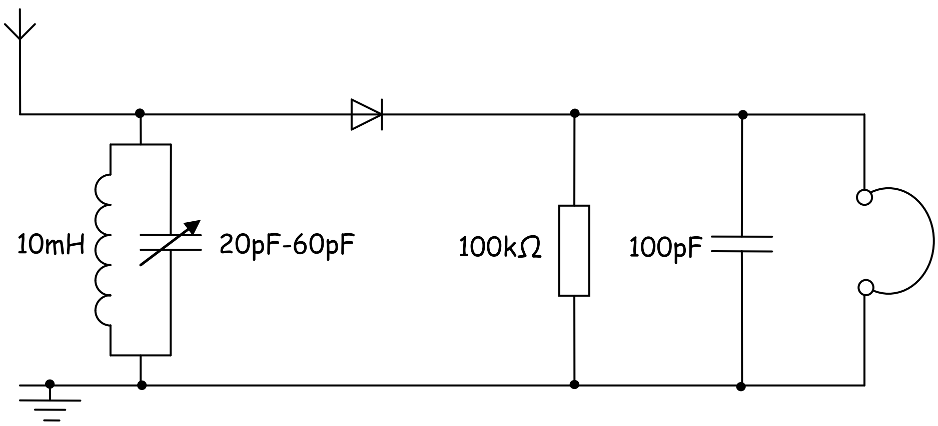
Topic 4.4.1 – Simple AM Receiver

There are only a couple of calculations that can be performed on this circuit, which are as follows:

i. using the tuned circuit components to calculate the range of frequencies that can be received by the radio, or given the frequency of a radio station, calculate the setting of the variable capacitor to ensure that this frequency is the one received.
ii. Calculating suitable values for the RF filter circuit, so that it has a high impedance to the audio signal, and low impedance to the RF carrier.

We will now look at a couple of examples to see how these various calculations are performed. However it is important to remember that all calculations will be based on a theoretical model, where loading effects will be ignored.

1. The following circuit shows a simple radio receiver



(a) Calculate the minimum and maximum frequency that the tuned circuit of this radio can respond to.

(b) (i) Calculate the break frequency of the RF Filter.

(ii) Comment on the suitability of the break frequency for this particular radio receiver.

Solution:

(a) To calculate the resonant frequency of the tuned circuit for minimum and maximum values of the variable capacitor we must apply the formula $f_o = \frac{1}{2\pi\sqrt{LC}}$ twice for the two extremes of capacitance value.

The minimum frequency will be obtained when C is at its maximum value i.e. 60pF, so

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

$$f_{o(\min)} = \frac{1}{2\pi\sqrt{10\times10^{-3}\times60\times10^{-12}}}$$

$$f_{o(\min)} = \frac{1}{2\pi\sqrt{6\times10^{-13}}} = 205468 \text{ Hz} \approx 205 \text{ kHz}$$

The maximum frequency will be obtained when C is at its minimum value i.e. 20pF, so

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

$$f_{o(\max)} = \frac{1}{2\pi\sqrt{10\times10^{-3}\times20\times10^{-12}}}$$

$$f_{o(\max)} = \frac{1}{2\pi\sqrt{2\times10^{-13}}} = 355881 \text{ Hz} \approx 356 \text{ kHz}$$

The tuning range of this tuned circuit is therefore 205 kHz – 356 kHz

(b) i. The break frequency of the RF filter is given by the following formula $\boldsymbol{f_b = \frac{1}{2\pi RC}}$

$$\begin{aligned} f_b &= \frac{1}{2\pi\times100\times10^{3}\times100\times10^{-12}} \\ &= 15915.49 \text{ Hz} \\ &\approx 16 \text{ kHz} \end{aligned}$$

ii. The audio frequency range broadcast on an AM transmission is limited to approximately 5 kHz. The break frequency is higher than the highest audio frequency so any audio signal that is broadcast will pass through the RF filter.

In addition the break frequency is much lower than any RF frequency that can be picked up by the receiver.

The RF filter is therefore suitable for this radio receiver.

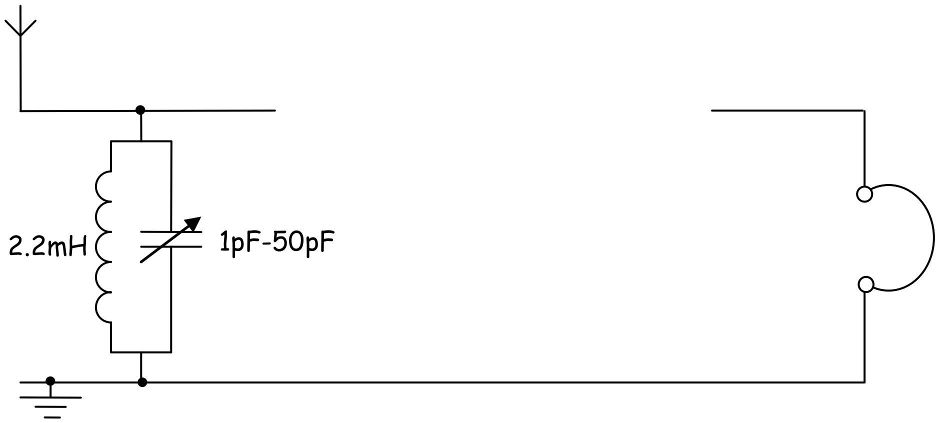
Note for the Enthusiast

1. The break frequency of the filter is 16 kHz
2. The time constant of the filter is 10 μs
3. The period of the audio signal is 200 μs at 5 kHz
4. The period of the carrier is a maximum of 5 μs
5. The impedance of the filter is approximately 90 kΩ

The values of R and C chosen hold up quite well when compared to the requirements stated earlier. The only exception is that the filter time constant is not long compared with the period of the carrier so a slight saw tooth effect would be superimposed on the audio signal.

The problem occurs in this case due to the relatively low carrier frequency

2. The following diagram shows an incomplete simple radio receiver.



(a) Complete the circuit diagram for a simple radio receiver, (component values are not required).

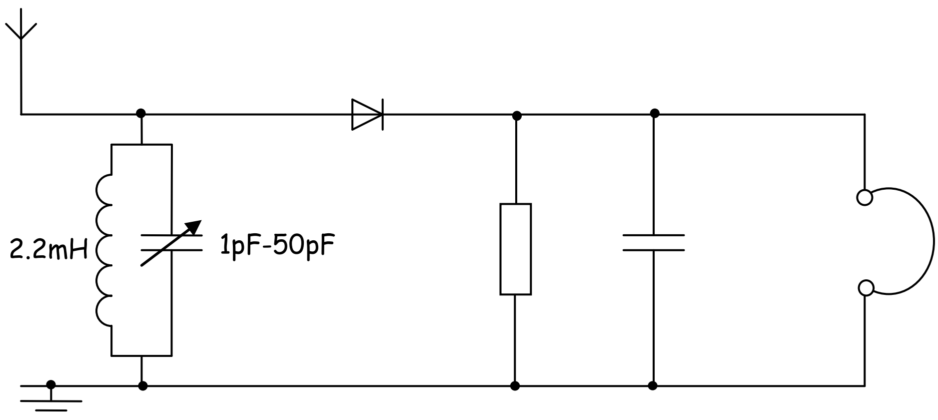
(b) The simple radio receiver is tuned to receive a radio station broadcasting on a carrier frequency of 1170 kHz.

(i) Calculate the value of impedance of the inductor at 1170 kHz.
(ii) State the value of impedance of the capacitor at 1170 kHz.
(iii) Calculate the value of C set on the variable capacitor to receive the radio station transmitting at 1170 kHz.

(c) The user would like to re-tune the radio to receive a radio station transmitting on a carrier frequency of 450 kHz. Show by calculation if this is possible.

Solution

(a)



(b) (i) The impedance of the inductor at resonance is given by the formula $X_L = 2\pi f_o L$, where the resonant frequency = 1170 kHz.

$$\begin{aligned} X_L &= 2\pi f_o L \\ &= 2\times\pi\times1170\times10^{3}\times2.2\times10^{-3} \\ &= 16172.91\ \Omega \\ &\approx 16173\ \Omega \end{aligned}$$

(ii) At resonance, the impedance of the capacitor will be the same as the impedance of the inductor, therefore $X_C = 16173\Omega$

(iii) Either using the formula for X_C

$$\begin{aligned} X_C &= \frac{1}{2\pi f_o C} \\ C &= \frac{1}{2\pi f_o X_C} \\ &= \frac{1}{2\pi\times1170\times10^{3}\times16173} \\ &= 8.41\times10^{-12}\ \text{F} \\ &= 8.41\ \text{pF} \end{aligned}$$

or re-arranging the resonance formula.

$$\begin{aligned} C &= \frac{1}{4\pi^2 f_o^2 L} \\ &= \frac{1}{4\times\pi^2\times\left(1170\times10^{3}\right)\times2.2\times10^{-3}} \\ &= 8.41\times10^{-12}\ \text{F} \\ &= 8.41\ \text{pF} \end{aligned}$$

(c) Either : calculate the lowest frequency the circuit can receive.

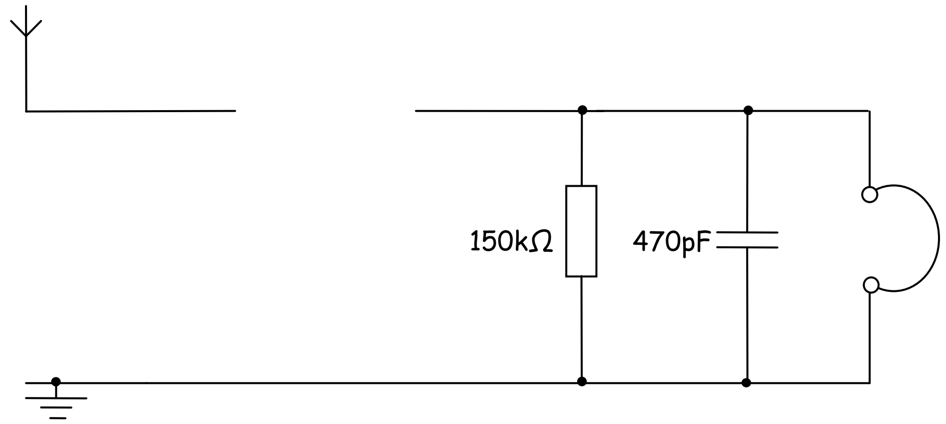
$$\begin{aligned} f_o &= \frac{1}{2\pi\sqrt{LC}} \\ &= \frac{1}{2\pi\sqrt{2.2\times10^{-3}\times50\times10^{-12}}} \\ &= 479870\,\text{Hz} \\ &\approx 480\ \text{kHz} \end{aligned}$$

or calculate the value of C required to receive the required station.

$$\begin{aligned} C &= \frac{1}{4\pi^2 f_o^2 L} \\ &= \frac{1}{4\pi^2\times(450\times10^{3})^2\times2.2\times10^{-3}} \\ &= 5.685\times10^{-11}\ \text{F} \\ &\approx 57\ \text{pF} \end{aligned}$$

Either method shows that the station transmitting on 450 kHz cannot be received. The lowest frequency that can be received is 480 kHz, and the second method shows that C would have to be set at 57 pF to make the resonant frequency 450 kHz.

3. The following diagram shows an incomplete radio receiver.



(a) Complete the circuit diagram for the simple radio receiver. (Component values are not required)

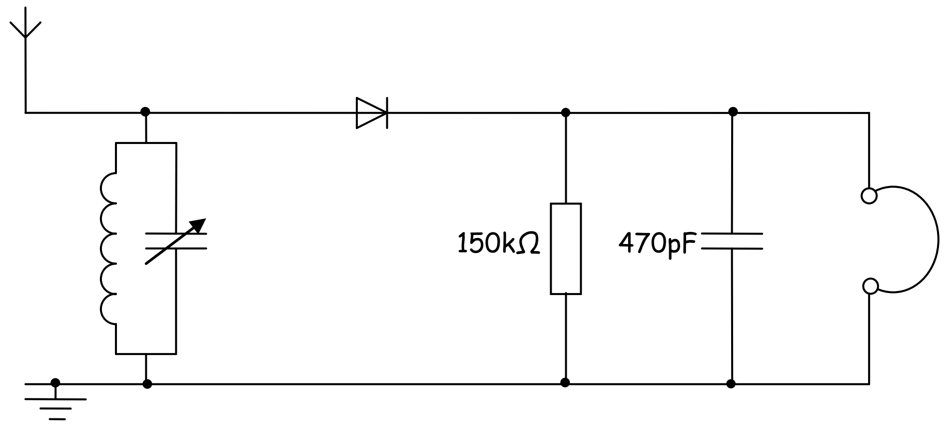
(b) The radio receiver must receive radio signals broadcast over the frequency range 350 kHz – 1350 kHz

(i) Calculate the break frequency of the RF Filter.

(ii) Comment on the suitability of the break frequency for this particular radio receiver.

Solution:

(a)



(b) i. The break frequency of the RF filter is given by the following formula $\boldsymbol{f_b = \frac{1}{2\pi RC}}$

$$f_b = \frac{1}{2\pi \times 150 \times 10^3 \times 470 \times 10^{-12}}$$
$$= 2257.5 \text{ Hz}$$
$$\approx 2.3 \text{ kHz}$$

ii. The audio frequency range broadcast on an AM transmission is limited to approximately 5 kHz. The break frequency is much lower than the highest audio frequency transmitted, therefore frequencies above 2.3 kHz will be attenuated. The RF filter is therefore un-suitable for this radio receiver.

Issues with the Simple Radio Receiver.

The simple radio receiver has two major problems.

1. It is not very sensitive – radio stations have to be very strong, to generate a large enough voltage in the antenna (aerial) to switch on the germanium diode. That is it cannot pick up weak stations.

2. It is not very selective – using a single tuned circuit it is difficult to obtain a high Q-factor which makes it difficult for the radio to select a single station without picking up a signal from any neighbouring stations and thus causing interference where two overlapping sounds can be heard.

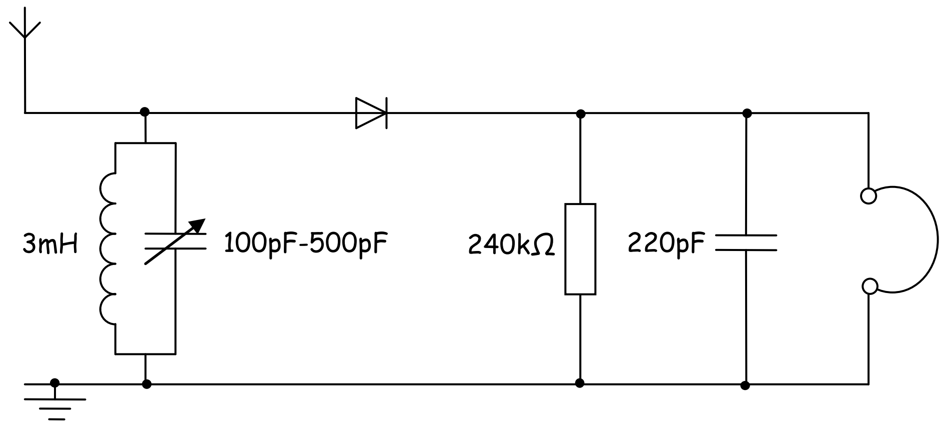
We will look at ways of improving these two flaws in our next topic – 4.2.2 Advanced Radio Receivers

Now here are a few questions for you to try.

Module ET4 – Communication Systems

Student Exercise 1

1. The following circuit shows a simple radio receiver



(a) Calculate the minimum and maximum frequency that the tuned circuit of this radio can respond to.

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(b) (i) Calculate the break frequency of the RF Filter.

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(ii) Comment on the suitability of the break frequency for this particular radio receiver.

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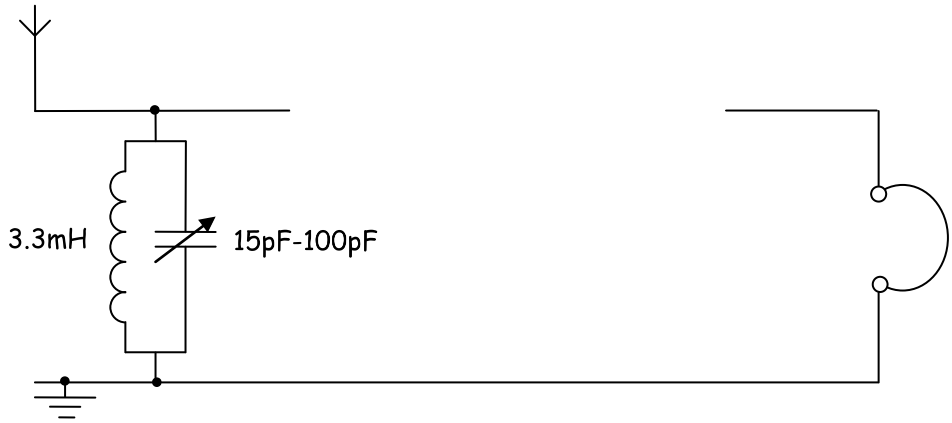
2. The following diagram shows an incomplete simple radio receiver.



(a) Complete the circuit diagram for a simple radio receiver, (component values are not required).

(b) The simple radio receiver is tuned to receive a radio station broadcasting on a carrier frequency of 680 kHz.

(i) Calculate the value of impedance of the inductor at 680 kHz.

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(ii) State the value of impedance of the capacitor at 680 kHz.

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(iii) Calculate the value of C set on the variable capacitor to receive the radio station transmitting at 680 kHz.

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(c) The user would like to re-tune the radio to receive a radio station transmitting on a carrier frequency of 350 kHz. Show by calculation if this is possible.

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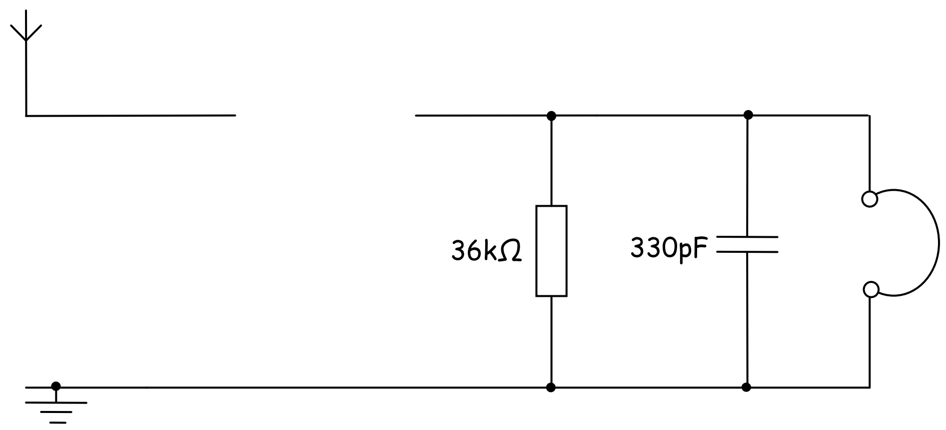
3. The following diagram shows an incomplete radio receiver.



(a) Complete the circuit diagram for the simple radio receiver. (Component values are not required)

(b) The radio receiver must receive radio signals broadcast over the frequency range 500 kHz – 1600 kHz

(i) Calculate the break frequency of the RF Filter.

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(ii) Comment on the suitability of the break frequency for this particular radio receiver.

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Solutions to Student Exercise:

1. (a) The minimum frequency will be obtained when C is at its maximum value i.e. 500 pF, so

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

$$f_{o(\min)} = \frac{1}{2\pi\sqrt{3\times10^{-3}\times500\times10^{-12}}}$$

$$f_{o(\min)} = \frac{1}{2\pi\sqrt{6\times10^{-13}}} = 129949\text{ Hz} \approx 130\text{ kHz}$$

The maximum frequency will be obtained when C is at its minimum value i.e. 100pF, so

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

$$f_{o(\max)} = \frac{1}{2\pi\sqrt{3\times10^{-3}\times100\times10^{-12}}}$$

$$f_{o(\max)} = \frac{1}{2\pi\sqrt{2\times10^{-13}}} = 290575\text{ Hz} \approx 291\text{ kHz}$$

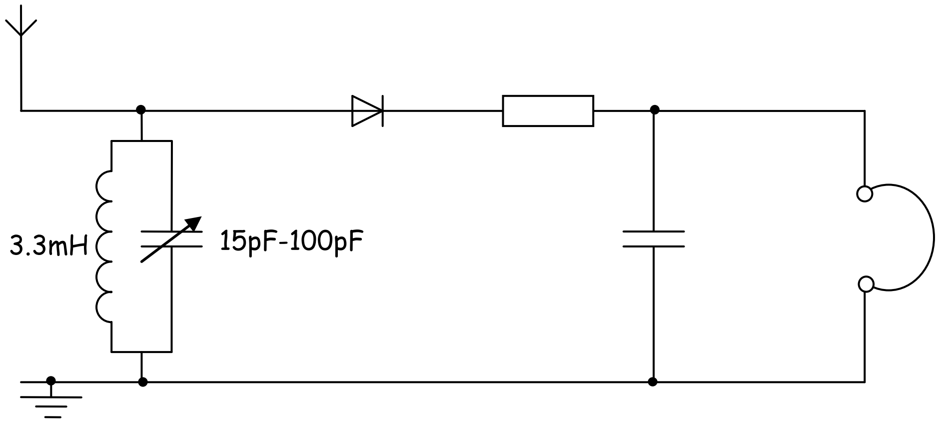
The tuning range of this tuned circuit is therefore 130 kHz – 291 kHz

(b) i. The break frequency of the RF filter is given by the following formula $\boldsymbol{f_b = \frac{1}{2\pi RC}}$

$$\begin{aligned} f_b &= \frac{1}{2\pi\times240\times10^{3}\times250\times10^{-12}} \\ &= 2652.58\text{ Hz} \\ &\approx 2.7\text{ kHz} \end{aligned}$$

ii. The audio frequency range broadcast on an AM transmission is limited to approximately 5 kHz. The break frequency is within the broadcast range and the RF filter is therefore un-suitable for this radio receiver.

2. (a)



(b) (i)

$$\begin{aligned} X_L &= 2\pi f_o L \\ &= 2\times\pi\times 680\times 10^3\times 3.3\times 10^{-3} \\ &= 14099.47\Omega \\ &\approx 14100\Omega \end{aligned}$$

(ii) At resonance, the impedance of the capacitor will be the same as the impedance of the inductor, therefore X_C = 14100 Ω

(iii) Either

$$X_C = \frac{1}{2\pi f_o C}$$

$$\begin{aligned} C &= \frac{1}{2\pi f_o X_C} \\ &= \frac{1}{2\times\pi\times 680\times 10^3\times 14100} \\ &= 1.659\times 10^{-11}\,\mathrm{F} \\ &= 16.59\ \mathrm{pF} \end{aligned}$$

or

$$C = \frac{1}{4\pi^2 f_o^2 L}$$

$$= \frac{1}{4 \times \pi^2 \times \left(680 \times 10^3\right)^2 \times 3.3 \times 10^{-3}}$$

$$= 1.660 \times 10^{-11}\,\mathrm{F}$$

$$= 16.60\ \mathrm{pF}$$

(c) Either :

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

$$= \frac{1}{2 \times \pi \times \sqrt{3.3 \times 10^{-3} \times 100 \times 10^{-12}}}$$

$$= 277053.19\ \mathrm{Hz}$$

$$\approx 277\ \mathrm{kHz}$$

Or

$$C = \frac{1}{4\pi^2 f_o^2 L}$$

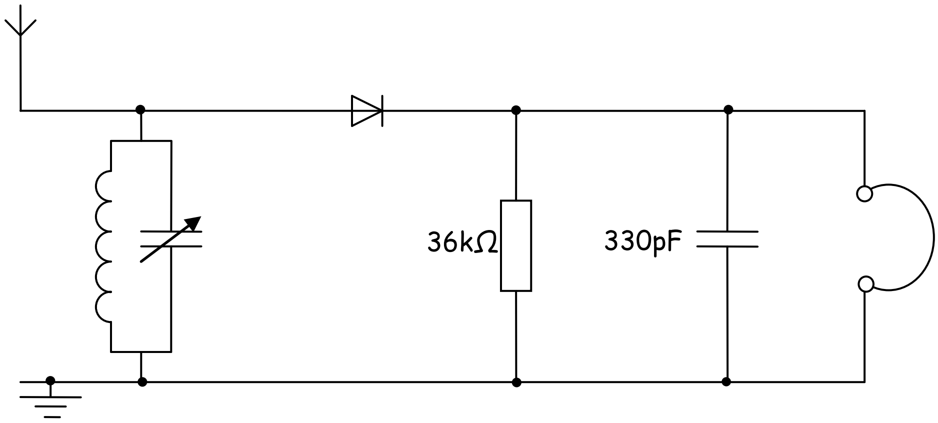
$$= \frac{1}{4 \times \pi^2 \times \left(350 \times 10^3\right)^2 \times 3.3 \times 10^{-3}}$$

$$= 6.265 \times 10^{-11}\,\mathrm{F}$$

$$\approx 63\ \mathrm{pF}$$

Either method shows that the receiver can receive a frequency of 350 kHz.

3. (a)



(b) i. The break frequency of the RF filter is given by the following formula $f_b = \frac{1}{2\pi RC}$

$$f_b = \frac{1}{2\pi \times 36 \times 10^3 \times 330 \times 10^{-12}}$$
$$= 13396.88 \text{ Hz}$$
$$\approx 13 \text{ kHz}$$

(ii) The audio frequency range broadcast on an AM transmission is limited to approximately 5 kHz. The break frequency is higher than the highest audio frequency so any audio signal that is broadcast will pass through the RF filter.

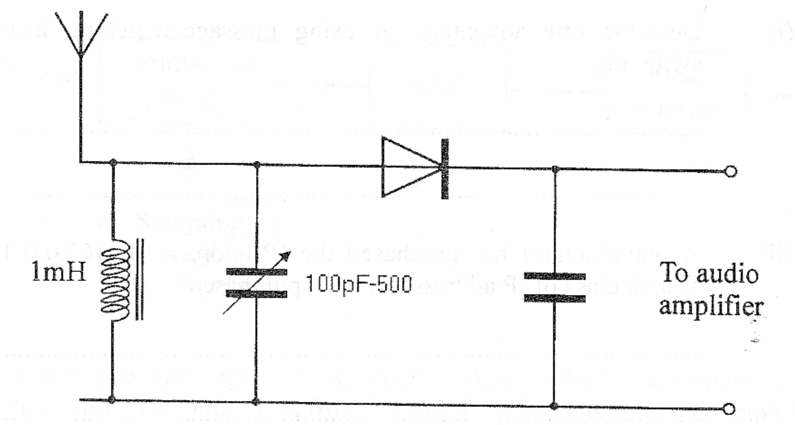
In addition the break frequency is much lower than any RF frequency that can be picked up by the receiver.

The RF filter is therefore suitable for this radio receiver.

Now for some examination style questions.

Examination Style Questions

1. The following shows the circuit diagram for a simple radio receiver.



a) Calculate the lowest frequency to which the receiver can respond.

....

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.... [3]

b) Describe and explain the part played by the following components in this receiver.

i) The diode

....

....

.... [2]

ii) The fixed capacitor

....

....

.... [2]

2. A simple radio receiver consists of the following sub-systems:

detector *antenna* *headphones* *RF filter* *tuned circuit*

(a) Draw the block diagram for this receiver.

[1]

(b) (i) Name the component used as the detector, which modifies the RF signal to give a non-zero average audio signal voltage.

....

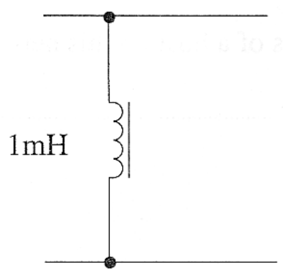
[1]

(ii) Name the component used as a demodulator, which separates the audio signal from the RF carrier.

....

[1]

(c) Here is part of the circuit diagram for the tuned circuit.



(i) Complete the diagram by adding the second component needed to allow the user to select different radio stations.

[1]

(ii) Choose a suitable range of values for this second component to allow the receiver to tune to radio broadcasts in the frequency range 500 kHz to 1000 kHz.
You must give the correct unit with your answer.

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[3]

(iii) The receiver is tuned to an AM radio station broadcasting on a carrier frequency of 800 kHz. The radio station broadcasts a signal ranging in frequency from 40Hz to 4 kHz. What is the lowest frequency the tuned circuit must respond to, in order to receive this signal?

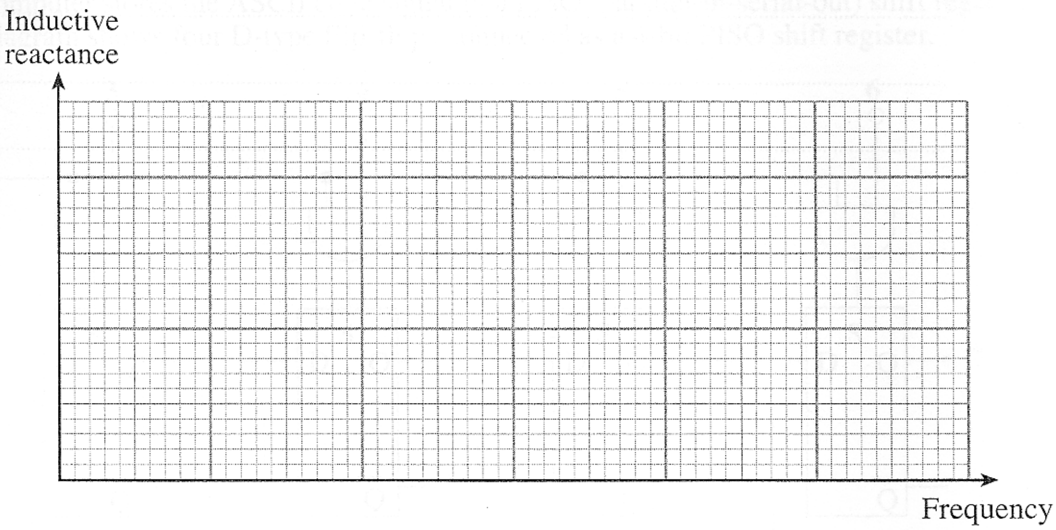
....

....

[1]

(iv) Sketch a graph to show how the inductive reactance of the inductor changes with frequency.

[2]



(v) At the resonant frequency of the tuned circuit, what is significant about the reactance of the inductor and the reactance of the capacitor ?

....

....

[1]

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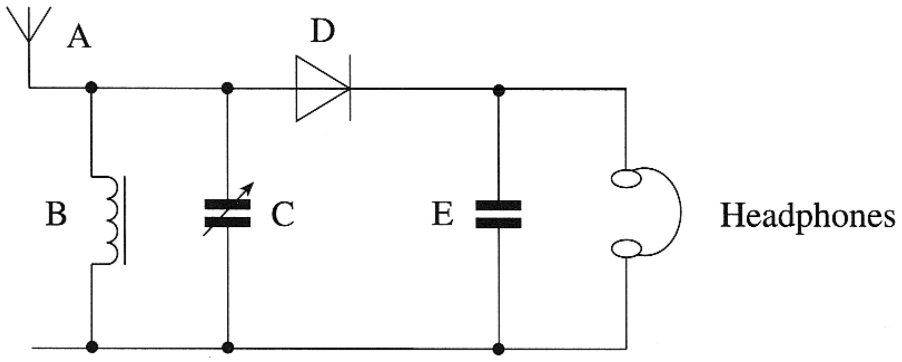
3. Here is the circuit diagram for a simple radio receiver.



(a) What is the name of the sub-system made up of components B and C?

....

[1]

(b) Component E is a 20nF capacitor.

(i) Calculate its reactance at a frequency of 200 kHz. Give the correct unit for your answer.

....

....

....

....

[2]

(ii) Estimate its reactance at audio frequencies.

....

[1]

(iii) Hence explain how the system demodulates the AM signal.

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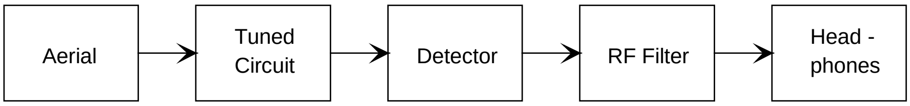
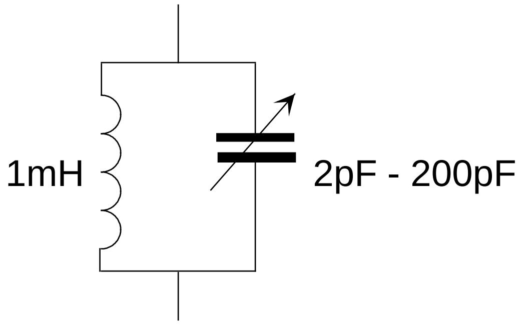
[3]

4. Here is a block diagram of a simple radio receiver.



a. The circuit diagram of the *Tuned circuit* is shown below.



i) Radio Wales transmits on a carrier frequency of 882 kHz. Calculate the reactance of the inductor at 882 kHz. Give the unit.

[2]

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....

ii) What should the reactance of the variable capacitor be if the circuit is to pick up Radio Wales.

[1]

....

iii) Calculate the value of the variable capacitor when receiving Radio Wales.

[2]

....

....

....

b. Name the component used as the detector in the simple radio receiver.

[1]

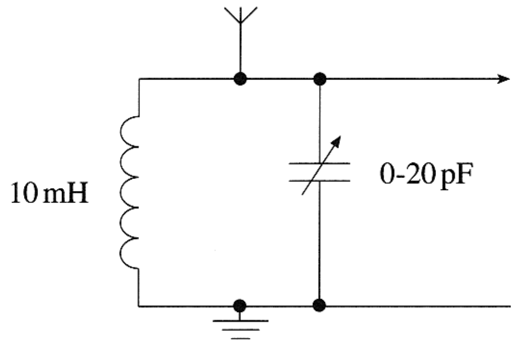
....

5. A tuned circuit is used in a radio receiver to select the desired radio signal from a range of signals present in the aerial.

a) The receiver is tuned to receive a carrier frequency of 1170 kHz with base bandwidth of 10 kHz. Sketch the frequency response required from the tuned circuit on the axes below. Label all **relevant frequencies**.

[2]

b) The following circuit diagram shows a suitable tuned circuit.



The radio is tuned to receive a carrier frequency of 1170 kHz.

i) Calculate the reactance of the inductor.

[1]

....

....

ii) What is the reactance of the variable capacitor for maximum signal output ?

[1]

....

iii) Calculate the value of the variable capacitor for maximum signal output.

[2]

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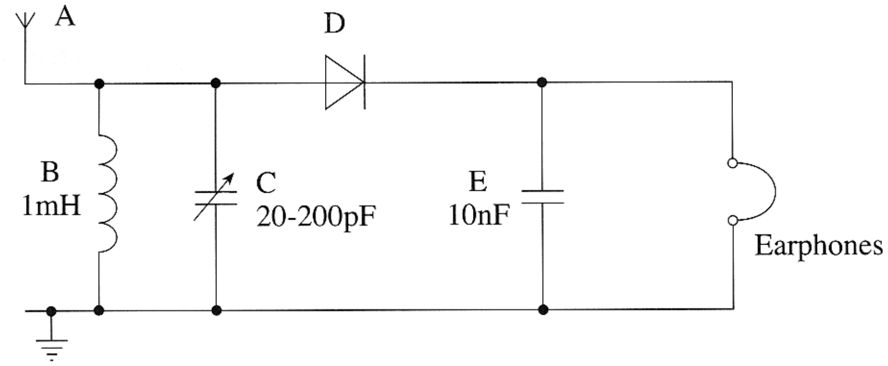
....

6. The circuit diagram for a simple radio receiver is shown below.



a. Use the letters A - E to answer the following questions.

i) Which component(s) modifies the RF signal to give a non-zero average audio signal. ....

ii) Which component(s) select the required RF signal ....

iii) Which component carries more than one RF signal ....

[4]

b. Calculate the highest frequency to which the above receiver can respond.

....

....

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....

[3]

c. The earphones and 10nF capacitor form the low pass filter for the radio. The impedance of the earphone is 1.2MΩ.

i. Calculate the break frequency of the filter.

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[2]

ii. State with reasons whether this RF filter is effective in this case.

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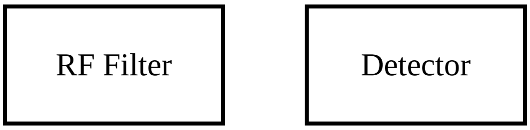
[2]

Topic 4.4.1 – Simple AM Receiver

7. The simple radio receiver is made from **five** functional blocks. Two of the blocks are shown below.



a) In the space below draw a block diagram to show how these blocks are connected together to make a crystal radio receiver.

[4]

b) What component is used in the detector block ?

[1]

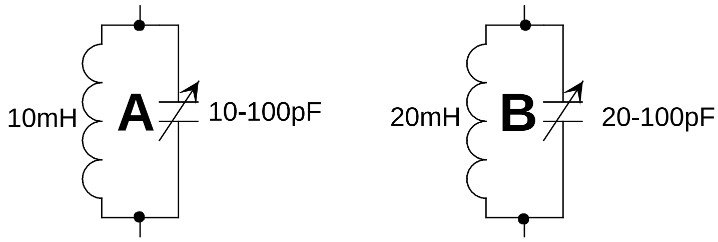
....

c) What component is used in the RF Filter block ?

[1]

....

d) Two possible tuned circuits for the radio are shown below.



Which circuit provides the user of the radio with the ability to select a frequency range between 120 kHz and 250 kHz. **You must show all of the calculations you have performed.**

[3]

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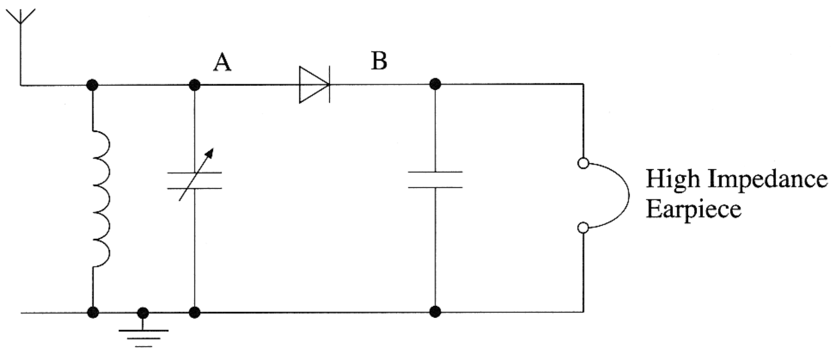
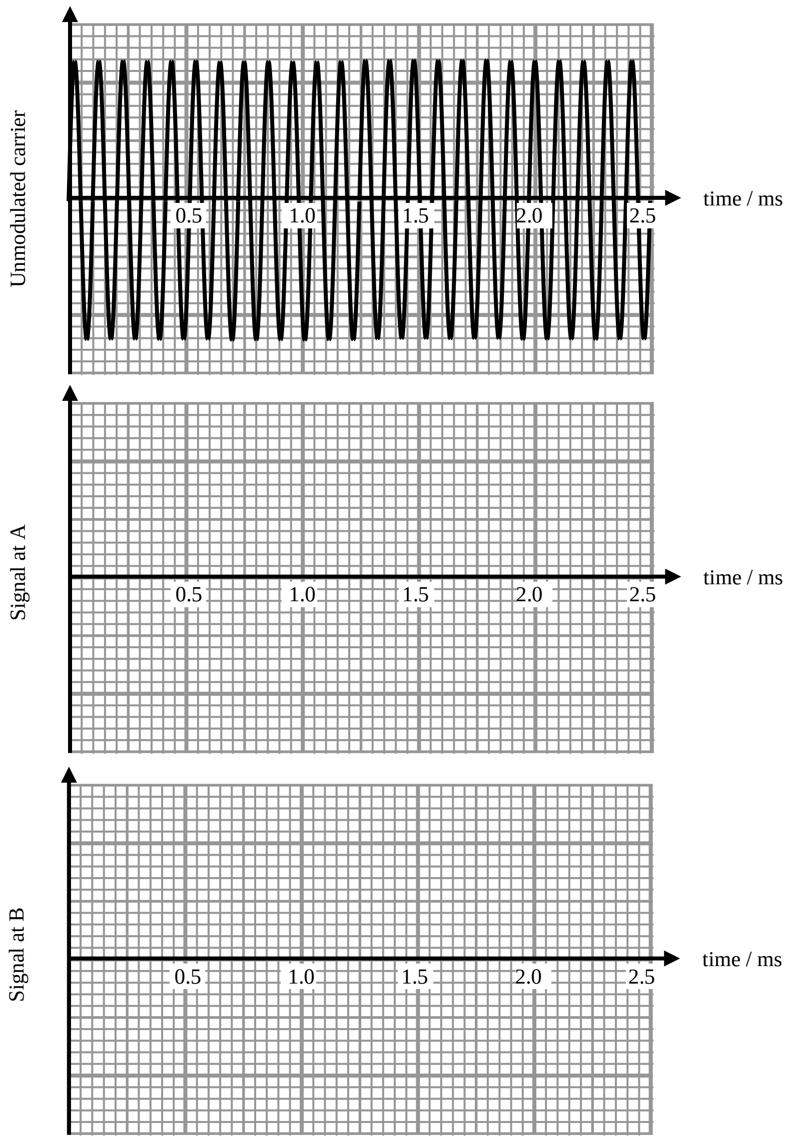
8. The following shows the circuit diagram for a simple radio receiver.

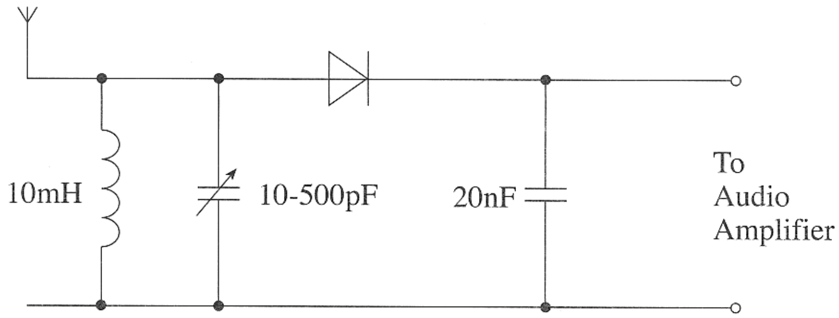


The receiver is tuned to receive a 1 kHz sine wave test signal, amplitude modulated onto a 100 kHz carrier wave Sketch the waveform you would expect to see on an oscilloscope at points A and B.

[3]



9. The following shows the circuit diagram for a simple radio receiver.



a. Explain the purpose of the following components in this receiver.

i) The inductor and variable capacitor.

....

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....
[1]

ii) The diode.

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....

....
[1]

iii) The fixed capacitor.

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....
[1]

b. Calculate the highest carrier frequency that the receiver can select. Give the unit.

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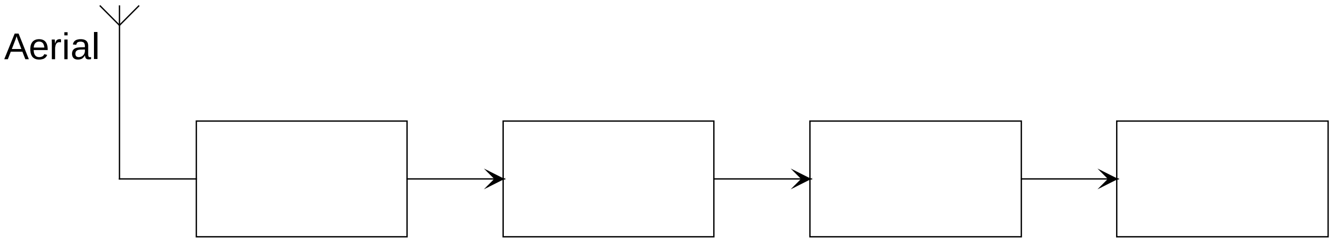
....
[3]

10. A simple radio receiver is made from the following sub-systems.

Detector *Tuned Circuit* *Headphones* *RF Filter*

a. i) Complete the block diagram of the simple radio receiver, using the subsystems above.

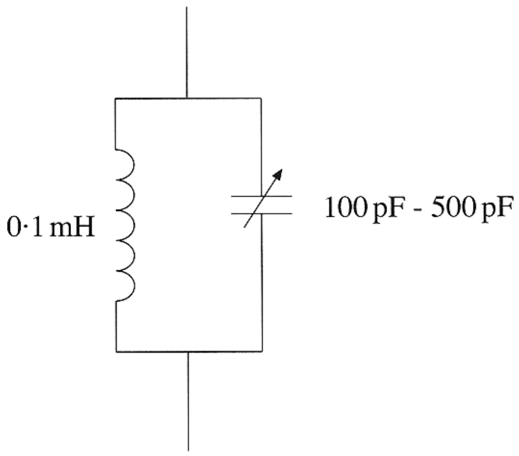


[1]

ii) Name the component used as the detector in the simple radio receiver.

....
[1]

b. The circuit diagram of the *tuned circuit* is shown below.



i) *Valleys Radio* transmits on a carrier frequency of 999 kHz. Calculate the reactance of the inductor at 999 kHz. Give the unit.

[3]

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....

....

ii) State the reactance of the variable capacitor when the circuit is tuned to pick up *Valleys Radio.*

[1]

....

iii) Calculate the value of the variable capacitor when receiving *Valleys Radio*.

[2]

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....

c. The simple radio receiver suffers from poor *selectivity* and *sensitivity*. What is meant by poor *sensitivity* ?

[1]

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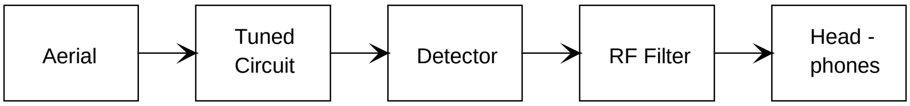
Topic 4.4.1 – Simple AM Receiver

11. Here is a block diagram of a simple radio receiver.



a. Name the component used as the detector in the simple radio receiver. [1]

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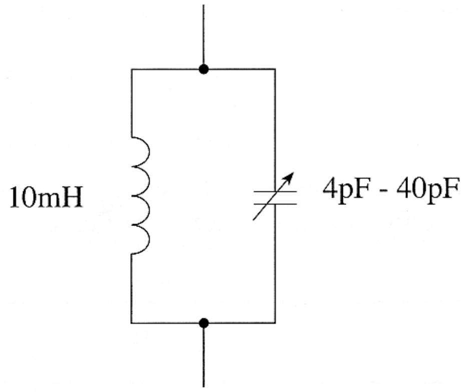
b. The circuit diagram of the ***Tuned circuit*** is shown below.



i) Radio Five Live transmits on a carrier frequency of 693 kHz. Calculate the reactance of the inductor at 693 kHz. Give the unit. [2]

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ii) What is the reactance of the variable capacitor at 693 kHz? [1]

....

iii) Calculate the value of the variable capacitor when tuned to receive Radio Five Live, at 693 kHz. [2]

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iv) Radio Five Live also broadcasts on 909 kHz. Show by calculation whether this tuned circuit can be adjusted to receive Radio Five Live at 909 kHz.

[2]

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....

c. The simple radio receiver suffers from *poor selectivity* and *poor sensitivity*. What is meant by the terms *poor selectivity* and *poor sensitivity*?

Poor selectivity means ....

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....

Poor sensitivity means ....

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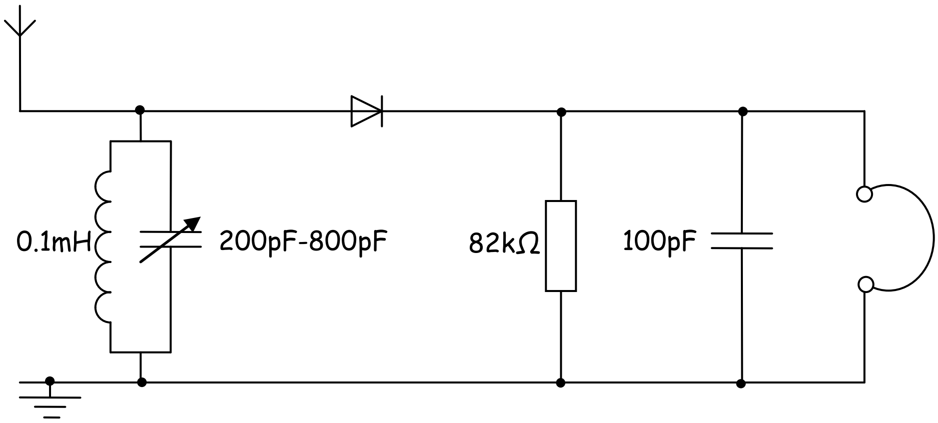
....

[2]

12. The following circuit shows a simple radio receiver



(a) Calculate the minimum and maximum frequency that the tuned circuit of this radio can respond to.

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[3]

(b) (i) Calculate the break frequency of the RF Filter.

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[2]

(ii) Comment on the suitability of the break frequency for this particular radio receiver.

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[2]

(c) The user would like to re-tune the radio to receive a radio station transmitting on a carrier frequency of 475 kHz. Show by calculation if this is possible.

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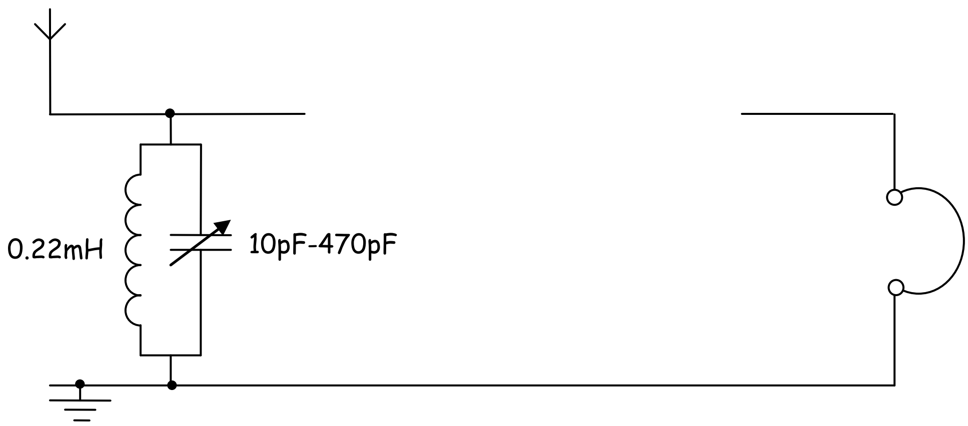
[3]

13. The following diagram shows an incomplete simple radio receiver.



(a) Complete the circuit diagram for a simple radio receiver, (component values are not required).

(b) The simple radio receiver is tuned to receive a radio station broadcasting on a carrier frequency of 2340 kHz.

(i) Calculate the value of impedance of the inductor at 2340 kHz.

....

....

....

[2]

(ii) State the value of impedance of the capacitor at 2340 kHz.

....

[1]

(iii) Calculate the value of C set on the variable capacitor to receive the radio station transmitting at 2340 kHz.

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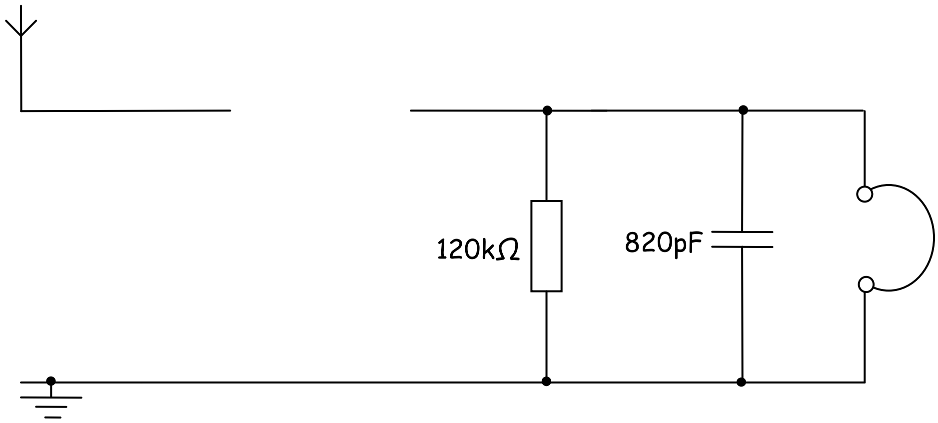
14. The following diagram shows an incomplete radio receiver.



(a) Complete the circuit diagram for the simple radio receiver. (Component values are not required)

(b) The radio receiver must receive radio signals broadcast over the frequency range 500 kHz – 1200kHz

(i) Calculate the break frequency of the RF Filter.

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[2]

(ii) Comment on the suitability of the break frequency for this particular radio receiver.

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[2]

Topic 4.4.1 – Simple AM Receiver

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Self Evaluation Review

Learning Objectives	My personal review of these objectives: ☺	😐	☹
draw a block diagram, and circuit diagram for a simple radio receiver, consisting of antenna, tuned circuit, detector/demodulator, and earphones;			
describe the function of each of these sub-systems;			
appreciate that a tuned circuit is a variable frequency band pass filter;			
design a tuned circuit to select a particular carrier frequency;			
select and use the equation $C = \frac{1}{4\pi^2 f_o^2 L}$ to calculate the value of C to provide a given resonant frequency.			
use the frequency response curves of a loaded tuned circuit to explain poor selectivity.			

Targets: 1. ……………………………………………………………………………………………

……………………………………………………………………………………………

2. ……………………………………………………………………………………………

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FOUR BAND CW TRANSCEIVER

(1999)

KLIK HIER VOOR DE NEDERLANDSE VERSIE

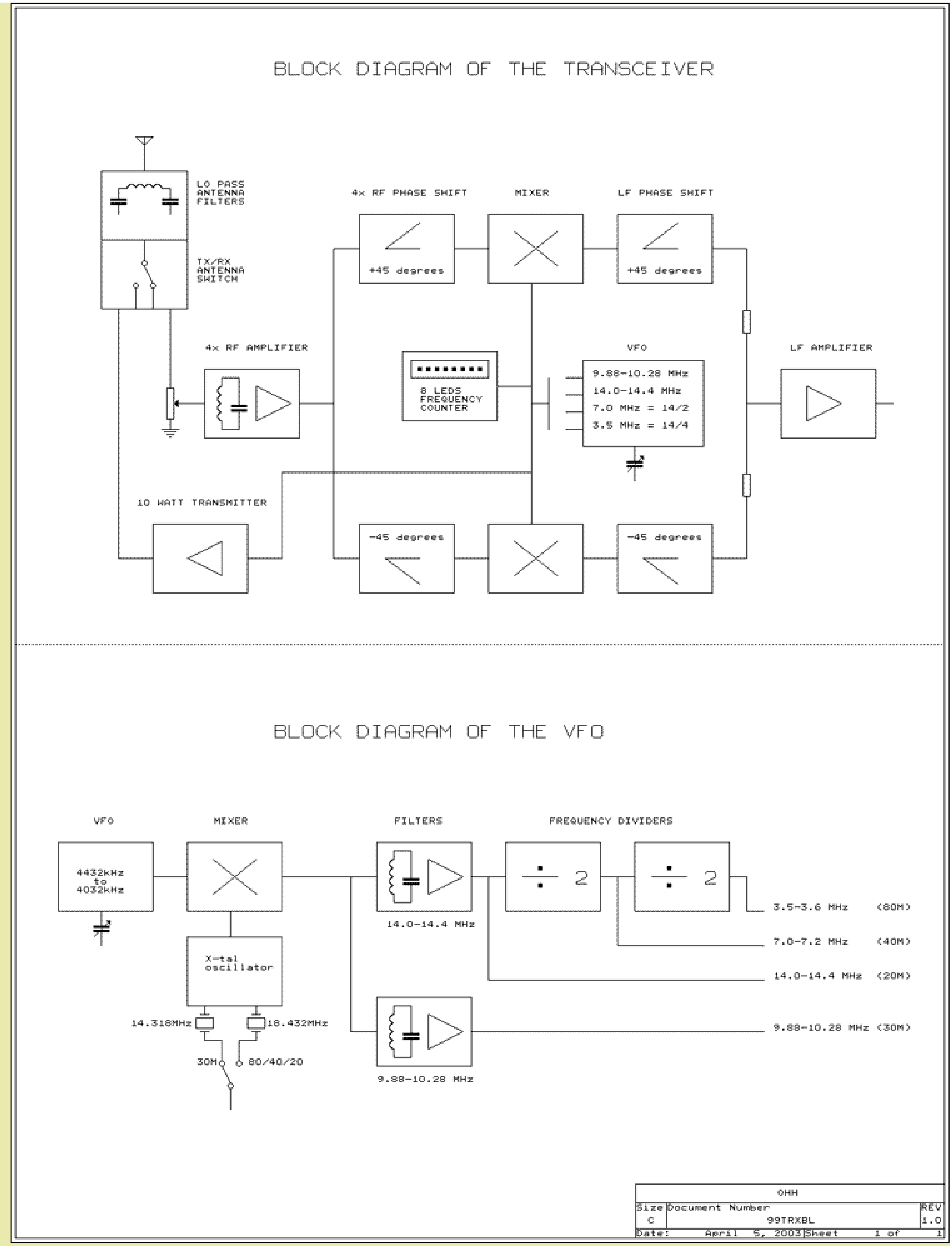
Four band CW transceiver with direct conversion receiver with sideband suppression.

Four band version of the 80 meter CW trx with dc receiver with sideband suppression
The performance of the 80 meter CW transceiver using the phase method for side band suppression is very good. Construction was easy with all good obtainable standard electronic components and without the expensive or complex crystal filter. Almost nothing is heard on the unwanted side band.
And a very big advantage is that you can use the same VFO for the transmitter without extra mixing and filtering! Therefore I had the plan to make a four band version to see how the performance of the phase method for suppression of a side band is for other amateur bands.

Restoration of my old three band CW transceiver with direct conversion receiver
The three band CW transceiver constructed in the beginning of my radio amateur carreer was my most used transceiver in that period.
But it had a lot of disadvantages. No 30 meter band, some frequency drift, no accurate frequency read out, a double side band direct conversion receiver, spurious emissions did not comply with the current limits. There were a lot of problems with 50 Hz hum due to the audio transformers and 88 mH inductances in the filters. Therefore, it was time for a restoration. I decided to dismount all the old printed circuit boards and keep them as a memory. Only the enclosure is used again, the damaged paint due to the intensive use in the shack and mobile while sailing is left in original state. It should become a four band version of the 80 meter band CW transceiver with the phase method used in the receiver. Adding the 30 meter band and also a simple frequency counter were the most important wishes.
Well, it became a success! Side band suppression is good. The four band transceiver is again my most used transceiver.

Details of the transceiver with single side band direct conversion receiver
Please read the page about the 80 meter band version for the details about the phase method and side band suppression.
Only the differences between the four band version compared with the 80 meter version will be discussed here.

The 4 band transceiver with single side band direct conversion receiver



Block diagram of the tranceiver

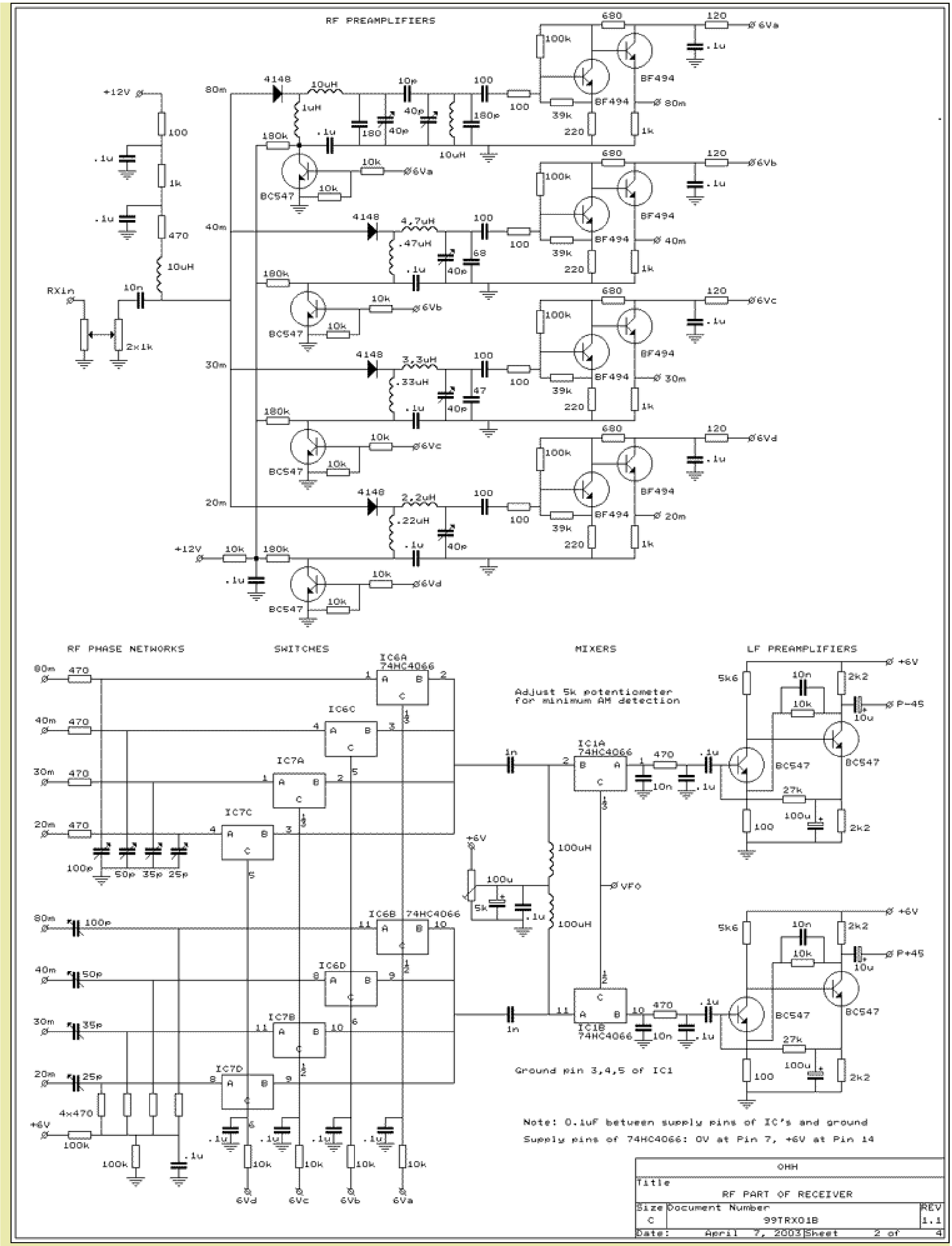
Block diagram of the transceiver

big diagram

Overview

The antenna signal is routed through a RF attenuator potentiometer to the four preselector circuits. It was easier to make four different RF amplifier than one with input / output switching circuits.
The RF signal is split into two signals that are shifted 90 degrees out of phase (one plus 45 and one minus 45 degrees). Both are mixed to audio frequencies. The two audio signals are again shifted 90 degrees out of phase (again one plus 45 and one minus 45 degrees). When we add the two signals, the signals of one side band are in phase, the signals of the other side band are 180 degrees out of phase and substracted.
The RF phase shift circuits are simple RC combinations (one per band), adjust the trimmers for maximum suppression at the centre of the CW band.
The VFO frequency is the reception frequency minus the audio beat tone. For 40 and 80 meters, the 20 meter VFO signal is divided by two and four.
In the audio circuit you will find a very efficient audio CW filter with two bandwidths, a mute switch and audio amplifiers plus a potentiometer for LF volume control.
The transmitter is a three stage 10 watt RF amplifier with keying circuit, input is the VFO signal via a potentiometer for the power control.
The antenna switch between transmitter and receiver is a diode switch for break-in operation without an annoying clicking relais.

THE RF PART OF THE DIRECT CONVERSION RECEIVER



RF part of the receiver

RF part of the receiver

big diagram

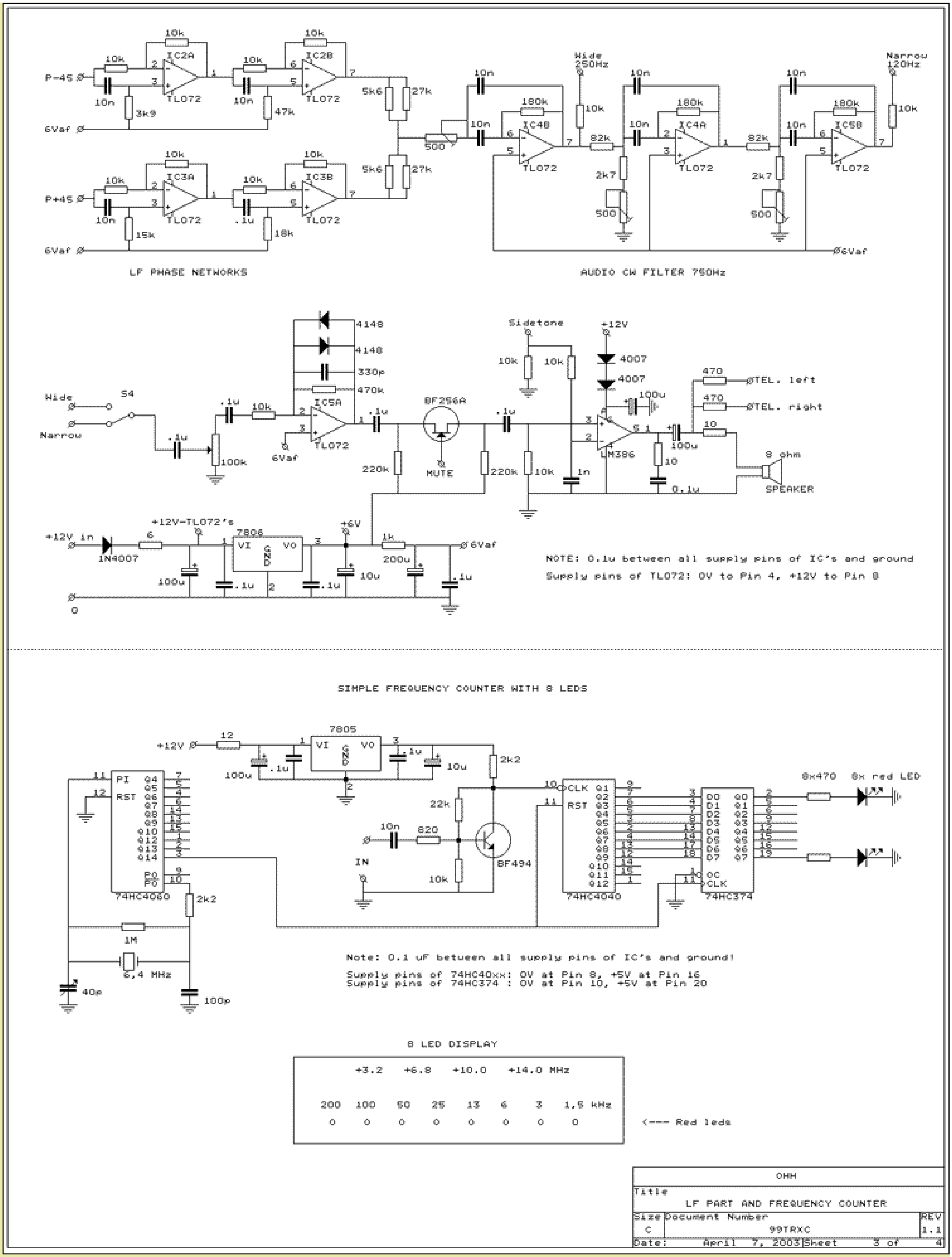
Preselector, RF preamplifier and RF phase shift networks

At the input, you will find the very standard and useful RF attenuator. Bandswitching is done by the diodes 1N4148. One diode conducts, the others are blocked and have a high negative blocking voltage of 12 volt. There is one preselector plus RF preamplifier per band. This was easier than one RF amplifier with switching circuits. After the preamplifiers we have the 45 degrees RF phase shift filters. It are simple RC networks, all tuned with the trimmers for approximately plus and minus 45 degrees phase shift. They also compensate for amplitude differences. Adjust them by ear, try different trimmer settings while adjusting the other while listening to a signal on the suppressed side band at centre frequency of that CW band. For the best settings for amplitude, it is possible that one network is plus 55 degrees, the other minus 35 degrees, but the difference should be 90 degrees.

Mixers and LF preamplifiers

The plus and minus 45 degrees phase shifted signals are mixed to LF frequencies by two mixers. These mixers are CMOS switches of a 74HC4066, very cheap and performance is good. Adjust the 5k potentiometer for minimum audio detection of strong broadcast stations.
The mixers are followed by two audio preamplifiers with transistors. They perform better than the op-amps in the first version of the four band transceiver.

AUDIO CIRCUIT AND SIMPLE FREQUENCY COUNTER



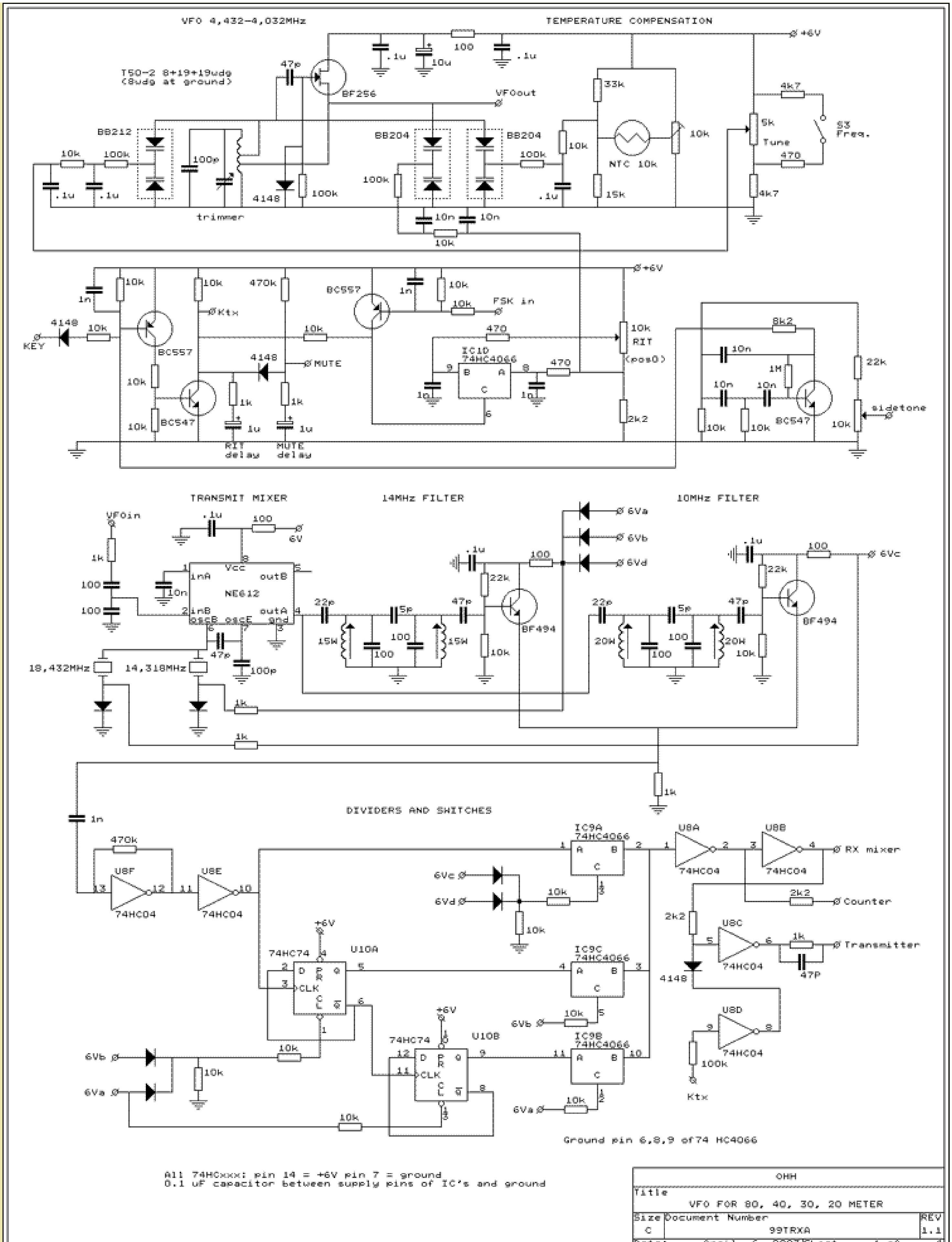
Audio and frequency counter

Audio and frequency counter
big diagram

LF circuit
The LF phase shift networks and CW filter are the same as that of the 80 meter version. Three potentiometers of 500 ohm are added to have the possibility of fine tuning (narrower or wider) of the CW filter. Low noise TL072 op-amps are used instead of the LM358. The LF switch is replaced by a volume potentiometer. The volume circuit is unusual, but in this way the gain of the LF amplifier decreases at lower volume settings. The advantage is that also the noise of the audio amplifier decreases. The diodes 1N4007 are added in the supply connection of the LM386 to lower the voltage with 1.4 volt. The maximum voltage of the LM386 is not exceeded when the supply voltage of the transceiver is 13.6 volt.

Simple frequency counter
The simple frequency counter is described somewhere else at this website and is also used in the 80 meter version of the transceiver. Eight leds are used to display the frequency, but when tuned to the desired band, only six are used. D7 and D6 are only used for tuning to the desired CW band:
For 80 meter, led D6 and D7 are always on.
For 40 meter, led D6 is off, D7 is on.
For 30 meters, D7 and D5 are off, D6 is on.
For 20 meters, D7 and D6 are off.
So only six are used to read the frequency within the band (five for 30 meters). Just add the values of the burning leds.

THE VFO PLUS RIT



Circuit diagram of the VFO

Circuit diagram of the VFO
big diagram

VFO
In the heterodyne VFO, two signals are mixed in a NE612 mixer. One of the signals is from the variable oscillator with a frequency range of 4.432 to 4.032 MHz. The other is from a crystal oscillator. For 10 MHz, the crystal frequency is 14.318 MHz, giving a frequency range from 9.886 to 10.286 MHz. For the other bands the cheap-crystal frequency is 18.432 MHz. This gives a frequency range of 14.0 to 14.4 MHz. This frequency is divided by two for 7 MHz and by four for 3.5 MHz.
There is also a temperature compensation circuit with the NTC. It is adjusted with the 10 k potentiometer while tuned at center frequency. I did that by measuring the frequency in the evening when the room temperature was 21 C and in the morning at 15 C. The frequency drift was considerably improved by this circuit.
The switch S3 is switched on for a smaller tuning range (CW band only) on the higher bands.
The VFO coil is wound on a T50-2 toroide. The coils in the bandfilters for 10 and 14 MHz are wound on 6mm cores. Adjust them for maximum output signal at the emitter of the BF494.

RIT
The RIT is activated by a CMOS switch of the 74HC4066 IC that also contains the two switches for the mixers. In the lowest position (pos 0), the VFO frequency is the same as the transmit frequency. Tune zero beat with a signal, then rotate the RIT potentiometer to the desired audio beat and mark it for that band.
The FSK input is never used, just delete it together with the transistor.

Mistake
The first version of the heterodyne VFO used a variable frequency of 4.0 MHz to 4.4 MHz and crystals of 6 MHz and 10 MHz for the 10 MHz and 14 MHz bands. This was a very bad choice, especcially for 30 meters. The frequencies of the variable oscillator (4.0 MHz to 4.4 MHz) and the crystal oscillator (6 MHz) are too close to each other. The difference of these signals, 1.6 MHz to 2 MHz caused a lot of spurious signals in the receiver and the transmitter. For a good heterodyne VFO, one frequency should always be higher than the final frequency or at least much higher than the other input frequency of the mixer.

THE 10 WATT CW TRANSMITTER

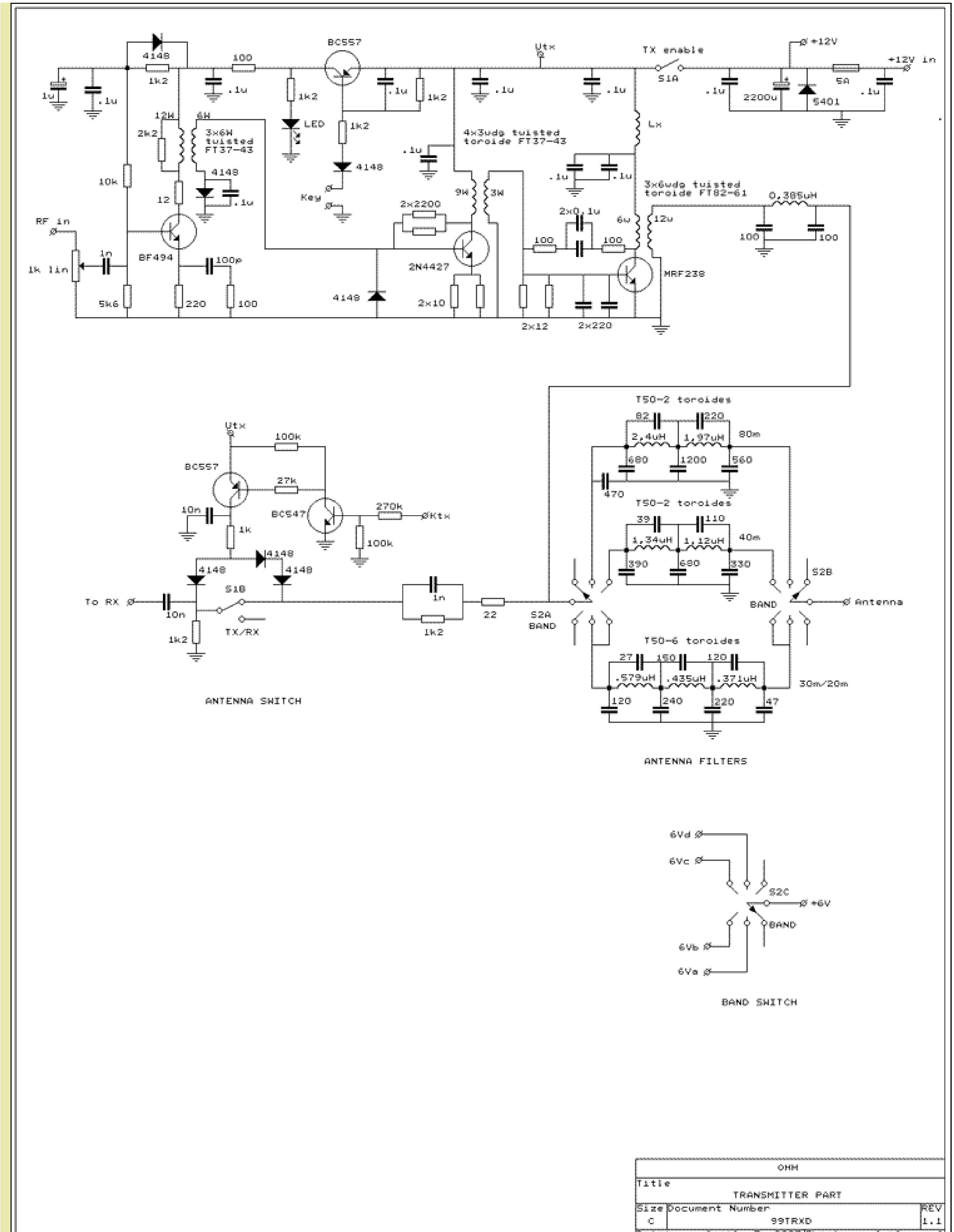


Diagram of the transmitter

big diagram

The transmitter explained

1st driver stage
With the 1k potentiometer, the output power can be adjusted from 0 to 10 watts. After this potentiometer, the signal is amplified by a BF494 transistor. This driver is switched by the morse key via the BC557 transistor. The diode and 1 uF capacitor are added for a correct shape of the CW signal.

2nd driver stage
The second driver is a 2N4427 transistor. The 2x2200 ohm resistors provide for RF feedback and DC voltage at the base of the driver transistor. The 2x10 ohm emitter resistors are a kind of limiter to prevent overdrive of the stage.

Final RF amplifier
Of course you should not use such an expensive VHF transistor but for example a 2SC1969. I had two MRF238 transistors unused in the junkbox, so why not.
The 2x 12 ohm at the base create a low input impedance, important for a good stability. The 220 pF capacitors have a low impedance for higher frequencies, they do prevent HF and VHF oscillations. And finally, the 2x 100 ohm resistors with the 2x 0.1 uF capacitors are a negative feedback circuit that prevent oscillations at frequencies below 1 MHz.
The output filters are wound on T50-2 and T50-6 cores. The number of windings is adjusted by checking the resonance frequency with a known capacitor (100 pF or so) and a dip meter.

Antenna switch
When in non-transmit mode, for maximum performance, the diodes are shortened by a switch to avoid any intermodulation problems. When in transmit mode, the antenna switch operates in break-in mode. The diodes are conducting when key-up and blocking if key down.

Notes
Built via the ugly method (dead bug method). Parts are soldered at one side of he double sided unetched print.
The VFO has to be placed in a screened enclosure. The frequency counter is also screened with chicken wire.... The advantage is that you can make some modification or adjustments through the holes of the chicken wire.
Inductances are commercially available types looking like big resistors. Lx are wired 6 hole cores.
Do not use a 74HCT type but a 74HC type for the IC's!

Performance
Sensitivity:
80 meter: -120 dBm
40 meter: -122 dBm
30 meter: -120 dBm
20 meter: -118 dBm

AM dynamic range:
80 meter: 95 dB (very good)
40 meter: 87 dB (good)
30 meter: 92 dB (good)
20 meter: 83 dB (acceptable)

Side band suppression:
80 meter: 40 dB
40 meter: 41 dB
30 meter: 43 dB
20 meter: 38 dB

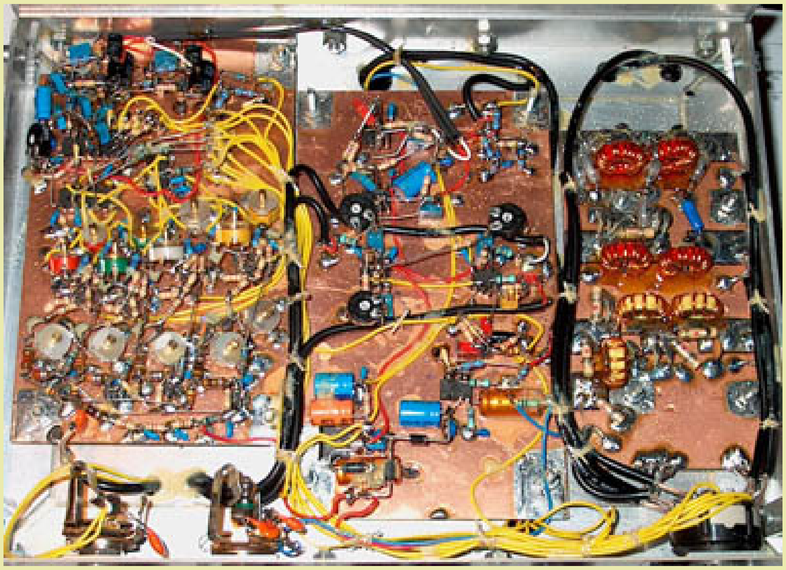
Transmit power:
Max. 10 W at 13.5 V

Suppression of harmonics:
Better than 45 dB, above 30 MHz better than 60 dB.

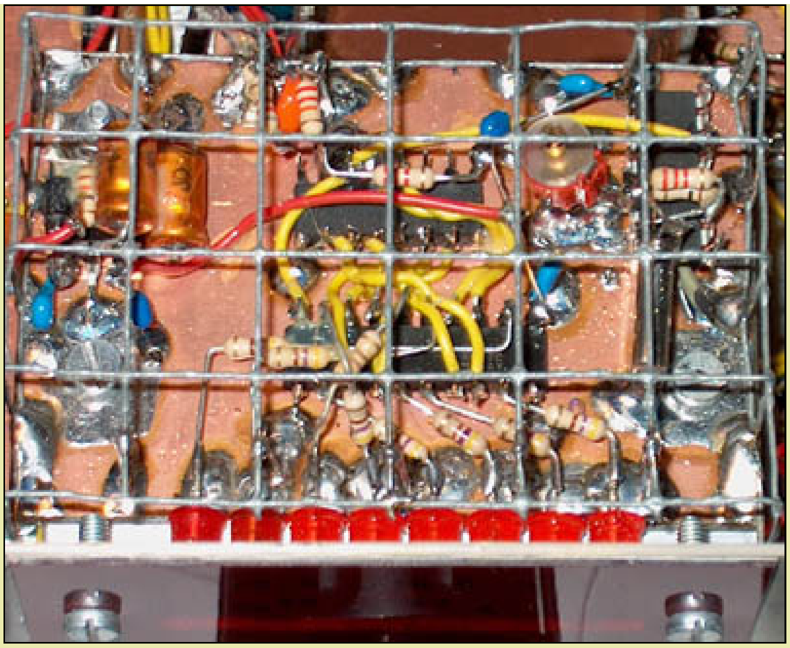
After restoration, it is a good transceiver for CW! Sometimes weak AM detection of very strong broadcast stations is heard but that disappears with some RF attenuation. My conclusion is that the phasing method for suppression of a side band is also suitable for a relative simple and uncomplicated transceiver with direct conversion receiver for the 40, 30 and 20 meter band.

PHOTOGRAPHS

Frequency counter, VFO, PA Driver and PA



Direct conversion receiver with sideband suppression, phasing networks, PA antenna filters.



The frequency counter with 8 leds, only 3 IC's and it's own 5 volt stabilizer.

BACK TO INDEX PA2OHH

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Back to Back Combined Single Feed Proximity Coupled Antenna with Dumbbell Shaped DGS

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ABSTRACT

Use of defected ground structure (DGS) to reduce the size of patch antenna is presented in this paper. In order to get a dipole like radiation pattern for some specific application a dumbbell shaped DGS is used in the common ground plane of back to back combined single fed proximity coupled antenna. A size reduction of about 60% is achieved. Parametric analysis has been done to see the resonance behavior of the antenna with DGS.

Keywords**:** *Defected Ground structure, Microstrip Antennas, Proximity Coupling*

1. Introduction

The continuous shrinking size of electronic equipments demands similar size antenna elements in order to fit properly in wireless devices without compromising the other radiation properties of the antenna. In this respect microstrip patch antennas are quite an obvious choice because of its other benefits like low profile, light weight, low cost and easy fabrication.

But as far as size of these patches concerned, the patch length should be around half-a-wavelength for the structure to act as a good radiator. Different techniques have already been used for the antenna size reduction such as using the substrate with high dielectric constant [1] , edge shorted patches with shorting plates or shorting walls, use of the shorting pin at the suitable position etc [2,3].

As far as our understanding goes much has not been reported regarding the use of DGS for size reduction of microstrip antennas, although its application have been reported for harmonic reduction [4], cross-polarization suppression [5] and mutual coupling reduction [6] in antenna arrays etc. Although the back to back geometries have been reported by the various researchers [7,8] but here a new coupling method *i.e.* proximity coupling with the defected ground structure is used for the consideration of the increased bandwidth.

This paper presents the application of DGS for size reduction of microstrip antennas. A dumbbell shaped DGS is used in the common ground plane of a back to back combined single feed proximity coupled microstrip antenna.

2. Defected Ground Structure

Recently there has been an increasing interest in the use of DGSs for performance enhancement of microstrip antennas and arrays. These are realized by etching off a simple shape defect from the ground plane of the planer circuits.

Although various complicated DGSs were reported in the literature, but the simplest one is the dumbbell shaped DGS. **Figure 1(a)** shows the simple and mostly used dumbbell shaped DGS that is etched in the ground plane below the microstrip line, in which both the areas (L_g*W_g) and the slot gap (g) play a very important role to find the resonance behavior of the DGS.

The head areas (L_g*W_g) is very useful for the variation in the inductance (L) and the slot (g) produces the capacitance (C). The L and C may be calculated from the formulae given below [9].

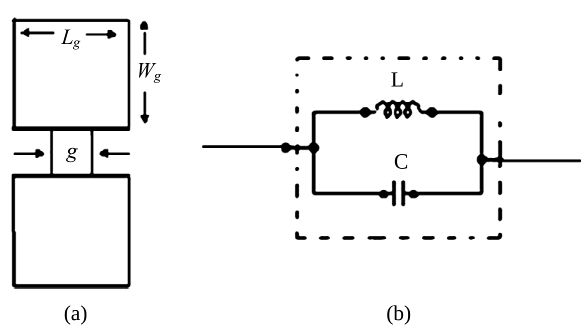


Figure 1. (a) Dumbbell shaped DGS, and (b) DGS Equivalent Circuit.

$$L = \frac{1}{4\pi^2 f_0^2 C} \quad (1)$$

$$C = \frac{f_c}{2Z_0} \times \frac{1}{2\pi(f_0^2 - f_c^2)} \quad (2)$$

When this DGS is applied to the antenna, the equivalent inductive part due to the DGS increases and produces equivalently the high effective dielectric constant, thereby decreasing the resonant frequency when the DGS is incorporated in the ground plane of a micro strip antenna.

3. Antenna Design with DGS

In this section, the design approach and the performance of the basic antenna and the antenna with DGS is described. At the outset, the single patch antenna was designed and simulated using the CST Microwave studio [10], for the operating frequency at 5.0 GHz. Then another patch of the same size was added in the opposite side of the ground plane and fed in the same way as the first one. The configuration seems as two patch antennas having a common ground plane working at the same frequency. Next the feed lines were combined for the antenna for single feed design. For this purpose the antenna feed lines W_f = 0.934 mm with d_f = 1.5 mm were designed of 100 ohm and for matching to the 50 ohm transmission line (W_p = 3.86 mm) a quarter wave length transformer (W_t = 2 mm) was used to give proper matching (**Figure 2**).

The cross-sectional view of the single fed back to back combined proximity coupled antenna is shown in the **Figure 2(a)**. The layouts of matching networks only are emphasized in this **Figure 2(b)** for convenience. It is observed that the antenna designed in this configuration gives the bandwidth of 137 MHz whereas single antenna gives a bandwidth of 67 MHz. This is due to the fact that as the antenna height increases the quality factor decreases and the bandwidth increases. This becomes a multilayer antenna with more height and higher bandwidth as compared to the single patch antenna.

The simple transmission line model was used for the antenna size calculation. The dielectric constant was taken as 3.38 with the loss tangent 0.0025 and of 1.524 mm thickness. The patch lengths L_p and widths W_p are 15 mm and 19 mm respectively. The feed line has been inserted inside the dielectric at a height equal to the half of the height (h = 3.048 mm) of the antenna on either side. The dumbbell shaped DGS with dimensions L_g = W_g = 8.6 mm and g = 0.76 mm was created in the ground plane of the antenna as shown in the **Figure 2(c)**. A small slot was also created for making the antenna with single feed. The two feed lines were connected with a metal strip which goes through the small slot in the ground plane. The fabricated antenna is shown in **Figure 2(d)**.

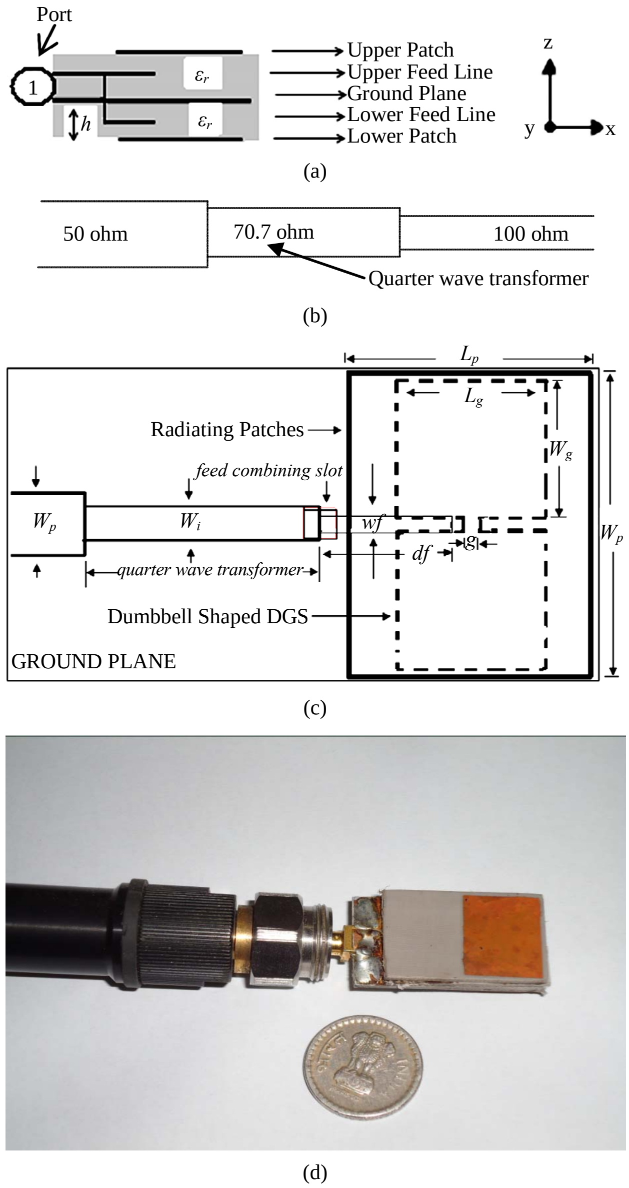


Figure 2. (a) Cross-sectional view of antenna configuration, (b) Feeding Network, (c) Top-View of the antenna, (d) Fabricated Antenna.

4. Results and Discussion

At first the antenna without the DGS in the common ground was simulated and was found to resonate at 5 GHz with 137 MHz Bandwidth.

Then the structure was simulated with the dumbbell shaped DGS. Before reaching to the final size of the DGS, a parametric study was done by varying L_g, W_g and g of

the DGS. As shown in **Figure 3**, with the increase in the value of L_g, the resonant frequency of the antenna is decreasing. Infect, increase in the length of the DGS head gives increasing inductance which in turn decreases the resonant frequency of the antenna.

At this point the increment in the (g) was not possible due to the accuracy in fabrication, so for this reason the other dimension (g) was kept constant for the requirement of the desired frequency (2 GHz). The size of the DGS single square head for the antenna to resonate at 2 GHz (UHF Band) was found to be 8.6 mm × 8.6 mm. The return loss (S11 [dB]) plot of the structure with and without DGS is shown in **Figure 4(a)**. **Figure 4(b)** shows the measured S11 parameter using the HP 8720 B network analyzer. The marker's position near to peak shows the resonance frequency 2.08 GHz with return loss of -13 dB. The result shows good agreement with the simulation results. The measured -10 dB bandwidth is about 60 MHz. The maximum size reduction achieved is about 60%.

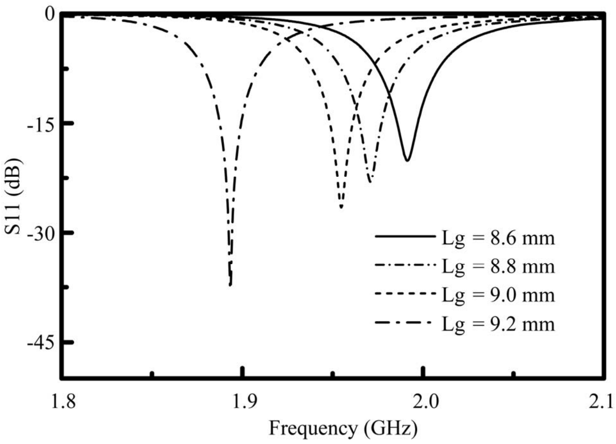
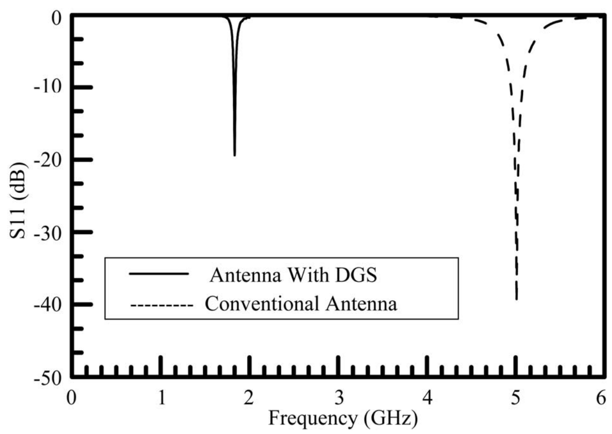
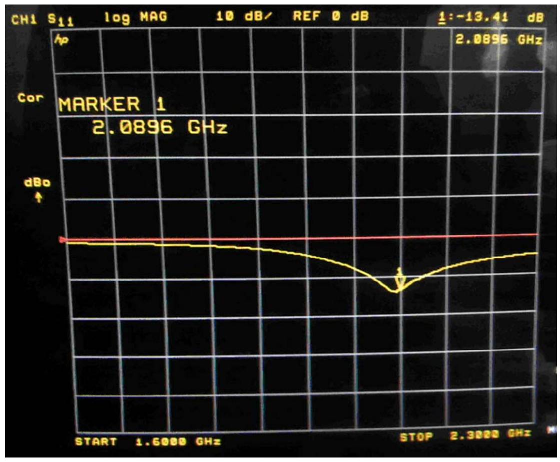


Figure 3. S11 Vs. Frequency response by varying DGS length (Lg).



(a)



(b)

Figure 4. Antenna Return Loss (a) simulated (b) measured.

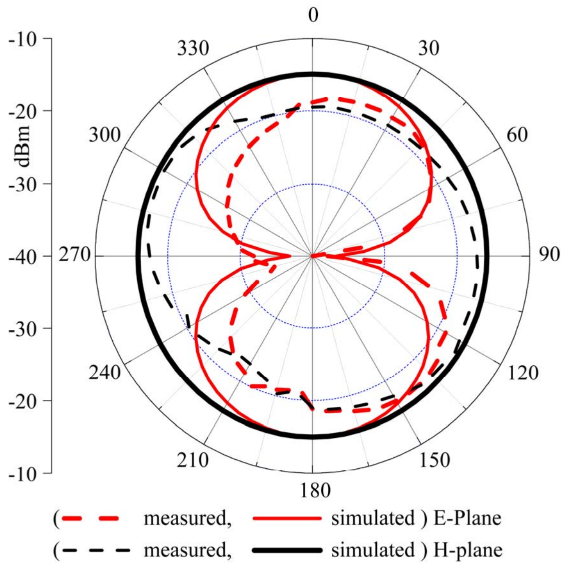


Figure 5. Antenna radiation pattern (measured and simulated) at 2 GHz Frequency.

The measured and simulated power patterns of the antenna are shown in **Figure 5**. It can be observed that the E-plane radiation pattern is similar to the pattern for a dipole antenna. Measurement errors are mainly due to the spurious radiation created by the feeding end and the improper coupling of the elements. However the gain measured experimentally for the proposed antennas with DGS is about -6.9 dB and -7.8 dB (where simulated gain with DGS is 3.8 dB and 5.7 dB is for the antenna without DGS, for both the planes) in both the E and H plane respectively, which is consistent with the size reduction of the antenna.

5. Conclusion

Microstrip patch antenna size reduction with DGS is car-

ried out in this work. A dumbbell shaped DGS in the common ground plane of a back to back microstrip structure was found to give a size reduction of about 60% and shifts the resonance frequency from 5 GHz to 2 GHz, with 60 MHz bandwidth facilitating the antenna, to be used for UHF band applications.

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[10] EM Simulation Software CST Studio Suite™, v9.

United States Patent [19]

Fletcher et al.

[11] **3,760,257**

[45] **Sept. 18, 1973**

[54] **ELECTROMAGNETIC WAVE ENERGY CONVERTER**

[76] Inventors: **James C. Fletcher,** Administrator of the National Aeronautics and Space Administration with respect to an invention of; **Robert L. Bailey,** Gainesville, Fla.

[22] Filed: **Sept. 27, 1972**

[21] Appl. No.: **292,698**

[52] **U.S. Cl.** **321/1.5,** 136/89, 250/212

[51] **Int. Cl.** **H02m**

[58] **Field of Search** 136/89; 250/212; 333/21; 321/1.5

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Primary Examiner—William M. Shoop, Jr.
Attorney—R. F. Kempf et al.

[57] **ABSTRACT**

Electromagnetic wave energy is converted into electric power with an array of mutually insulated electromagnetic wave absorber elements each responsive to an electric field component of the wave as it impinges thereon. Each element includes a portion tapered in the direction of wave propagation to provide a relatively wideband response spectrum. Each element includes an output for deriving a voltage replica of the electric field variations intercepted by it. Adjacent elements are positioned relative to each other so that an electric field subsists between adjacent elements in response to the impinging wave. The electric field results in a voltage difference between adjacent elements that is fed to a rectifier to derive d.c. output power. The element pairs may be arranged in a two-dimensional array to provide power conversion of randomly polarized electromagnetic waves, such as sunlight.

19 Claims, 3 Drawing Figures

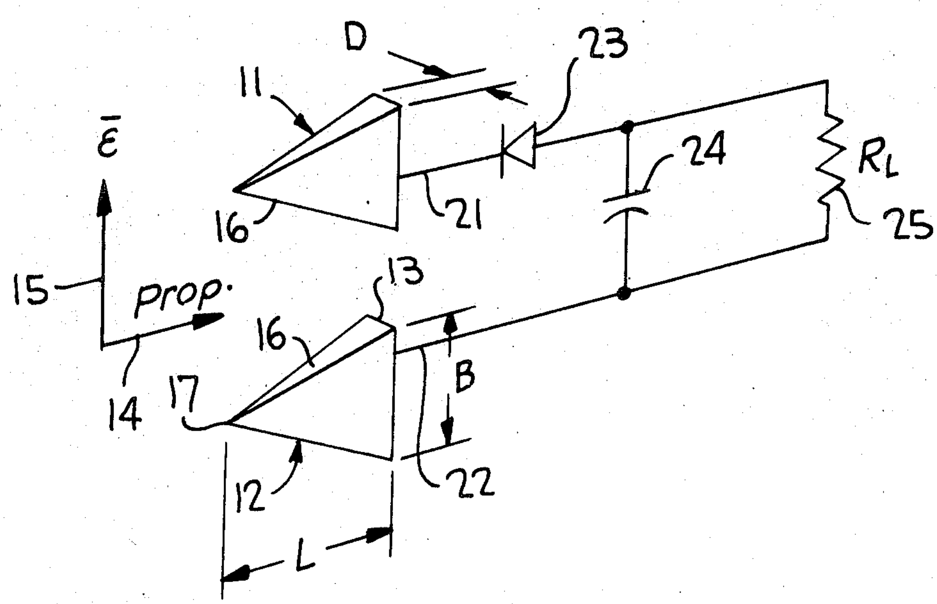


FIG. 1

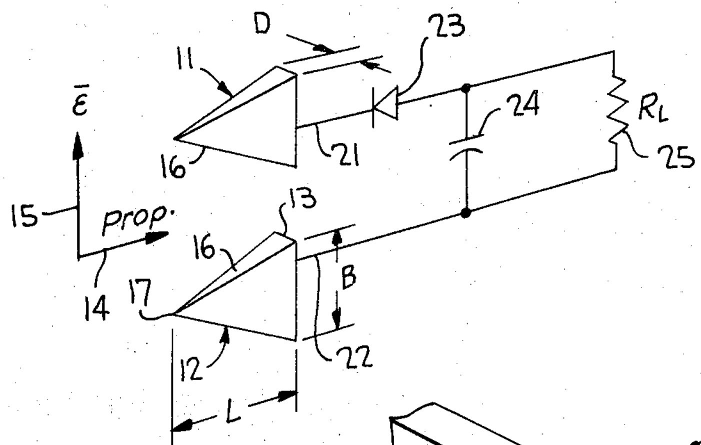
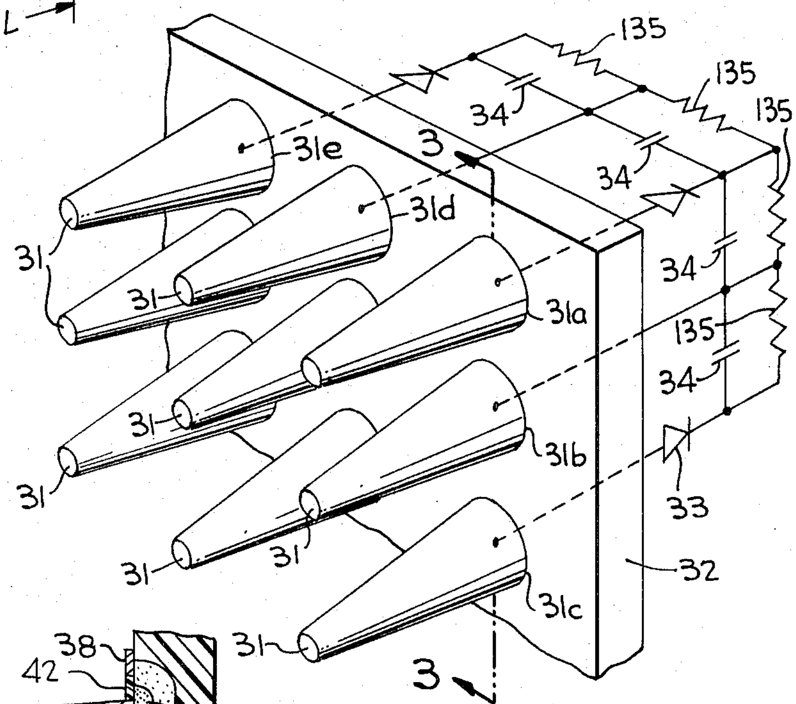


FIG. 2



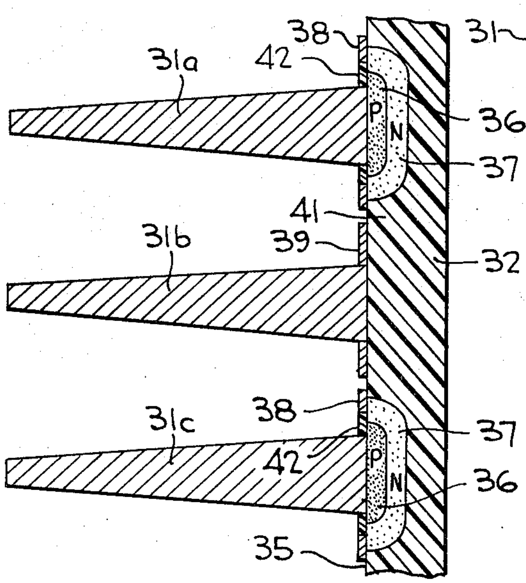


FIG. 3

ELECTROMAGNETIC WAVE ENERGY CONVERTER

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 U.S.C. 2457).

FIELD OF INVENTION

The present invention relates generally to devices for converting electromagnetic wave energy into electric power and, more particularly, to a device including a number of relatively closely spaced electromagnetic wave absorber elements having tapered portions responsive to wide band electromagnetic wave radiation.

BACKGROUND OF THE INVENTION

Devices for converting radiant energy into usable power have been considered extensively in the past. Presently, the most commonly utilized devices for converting radiant energy into usable power are solar cells which are adapted to convert solar energy directly into electricity for power generating purposes. Solar cells generally include oppositely doped semiconductor junctions which generate current in response to solar energy impinging thereon. Solar cells depend for their operation on quantum properties of light energy to provide charge separation and hence current flow in the junction region. To date, the maximum efficiency of solar cells in converting solar energy into electric energy is approximately 13 percent. In addition to the relatively low conversion efficiency of solar energy into electric power, solar cells are very expensive, as well as fragile, and usually must be mounted on a rigid, preferably flat substrate. The requirement for a rigid, flat substrate frequently substantially increases the combined cost of the solar cells and their supporting structure; if the supporting structure is a spacecraft panel, problems of folding the panel and maintaining it in a rigid condition in use are encountered.

BRIEF DESCRIPTION OF THE INVENTION

In accordance with the present invention, the wave properties of electromagnetic energy are utilized to convert wide band electromagnetic wave energy into usable electric power. The wide band energy impinges on an array of tapered absorber elements mutually insulated from each other. The length, base area, and separation of the elements are such that relatively wide band energy can be absorbed. To achieve maximum conversion of wide band energy, each element has a length, in the direction of wave propagation, equal to several wavelengths of the longest wavelength energy to be converted. Adjacent elements have spaced, sloping converging sides to enable maximum conversion of energy wavelengths in the spectrum to be converted. A voltage replica of the electric field variations absorbed by each element is derived at an output of each element. The difference between the voltage variations derived from adjacent elements is derived and supplied to a rectifier to provide the power conversion. To maximize the voltage difference, bases of adjacent absorber elements are spaced from each other by less than one wave length and preferably less than ½ wavelength, of the received energy. The close spacing, relatively long length and tapered sides also enable the absorber elements to function effectively as absorbers and prevent substantial re-radiation and reflection of the energy impinging thereon because the wave radiation is trapped in the converging interstices between the abosrbing elements.

In a preferred embodiment, the absorbers are formed of metallic elements, such as copper or other suitable material; however, absorbers may consist of dielectric elements which function to direct the electromagnetic wave energy onto an electromagnetic wave energy-to-electric voltage converter that derives a voltage replica of the wave energy.

The invention may be utilized in conjunction with converting wave energy from the microwave region through the visible light spectrum. If the invention is utilized for wave lengths in the solar spectrum, it is ideally suited for use as a solar energy-to-electric power converter. In such a configuration, the absorber elements and electric components utilized for converting the voltage wave replicas into electric power might be formed utilizing integrated circuit type manufacturing processes.

If the device is utilized for absorbing plane polarized electromagnetic waves, adjacent elements in the direction of the wave electric field are aligned with each other in pairs such that maximum electric field variations are derived between them but adjacent elements at right angles to the electric field are packed as close as possible to each other without electric contact, to maximize the active absorber area. If the electromagnetic wave radiation is circularly or randomly polarized, as in the case of solar energy, a two-dimensional array of elements is provided. The elements of the two-dimensional array are positioned in mutually orthogonal directions having aligned columns and rows, and the elements preferably have symmetrical bases, such as a square or circle. Voltage differences are derived between adjacent pairs in both orthogonal directions to provide maximum conversion efficiency of the circularly or randomly polarized wave energy.

Because the conversion process is in response to the wave properties of the impinging electromagnetic wave energy, rather than the quantum properties of such waves, and because of the small number of loss mechanisms individually and collectively optimal, it is believed possible to achieve conversion efficiencies considerably greater than existing solar cell type devices. A major advantage of the present invention is the separation of the wave absorption means and the conversion means permitting each to be individually optimized for the incident wave electromagnetic power spectrum. Another major advantage is that by suitable choice of geometry for the absorbing elements the device can be made to match the incident radiation spectrum. There is no known means of achieving this desirable result with present art solar cells. Another advantage of the present invention is that it does not utilize temperature-sensitive active semiconductor elements, for the basic absorption process; the only semiconductor components are passive diodes. A further advantage of the present invention is that the substrate on which the elements are mounted can be mechanically flexible, to substantially eliminate many of the problems inherent with prior art fragile solar cells mounted on rigid substrates.

It is, accordingly, an object of the present invention to provide a new and improved device for converting electromagnetic wave energy into electric power.

Another object of the invention is to provide a new and improved device for converting wide band electromagnetic wave energy into electric power with relatively high efficiency, utilizing the wave properties of the energy.

An additional object of the invention is to provide a new and improved device for converting circularly or randomly polarized electromagnetic wave energy into electric power in response to electric field gradients.

A further objet of the invention is to provide a relatively inexpensive device for converting electromagnetic wave energy into electric power, which device is relatively temperature-insensitive and can be mounted on a flexible substrate.

An additional object is to provide a new and improved integrated circuit type device for converting solar energy into electric power.

An additional object is to provide a new and improved means of matching the response of the device to the incident electromagnetic wave spectrum.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of several specific embodiments thereof, especially when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a perspective view schematically illustrating the principles of the present invention;

FIG. 2 is a perspective diagram illustrating an embodiment of the invention particularly adapted for converting solar energy into electric power; and

FIG. 3 is a side sectional view of the embodiment illustrated in FIG. 2, along the lines 3—3.

DETAILED DESCRIPTION OF THE DRAWING

Reference is now made to FIG. 1 of the drawing wherein is illustrated a pair of mutually insulated, substantially identical, pyramidal or conical, aligned and relatively closely packed, preferably metallic, as copper or other suitable material, electromagnetic wave absorber elements **11** and **12** which are responsive to plane polarized wide band electromagnetic wave energy that is propagating in a direction indicated by arrow **14** and has an electric field with a gradient in a direction indicated by arrow **15**. Elements **11** and **12** are constructed so that the shapes of every cross section parallel to their bases **13** are similar; the cross-sectional areas decrease for increasing distances from the bases **13** of the elements. Each of elements **11** and **12** includes a co-planar base **13**, which may have any desired configuration, such as a rectangle, square or circle, that lies in a plane at right angles to the direction of wave propagation and is parallel to the electric field gradient **15**. Elements **11** and **12** have a substantial height, L, or length in the direction of wave energy propagation, between their base **13** and apex **17**. The height is generally several (up to approximately seventy five) wave lengths of the longest wavelength of the incident electromagnetic energy. Elements **11** and **12** include adjacent, tapered side surfaces **16** that converge toward base **13** and are positioned relative to each other to intercept the electric field **15** and absorb energy over a wide band of the electromagnetic wave. The apex of absorber elements **11** and **12** may be truncated in which case L is the length of the truncated absorber elements.

Voltage variations derived in elements **11** and **12** in response to the electric field variations of the electromagnetic wave energy impinging on surfaces **16** are transduced or converted into an electric voltage at terminals **21** and **22** of the elements. The voltages at terminals **21** and **22** are replicas of the electric field variations impinging on absorber elements **11** and **12**, whereby the voltage difference between terminals **21** and **22** is proportional to the electric field gradient established by the plane polarized wave between facing surfaces **16** of elements **11** and **12**.

The centerline spacing between adjacent elements **11** and **12** is such that for the incident electromagnetic wave spectrum, maximum voltage between **21** and **22** occurs. It is of the order of a wavelength or less of the incident electromagnetic energy. The present invention responds to this voltage difference as derived over the desired spectrum of the incident wave energy, to convert the wave energy into electric power.

The voltage difference between terminals **21** and **22** is converted into useful d.c. electric power by a rectifier **23** and a filter capacitor **24**, the voltage across which is supplied to a suitable external load, such as resistor **25**. The cathode is connected between the anode of the rectifier diode and terminal **22**. It is to be understood that a full wave rectifier can be employed and that the d.c. voltage developed across external load **25** can be supplied to any suitable device, such as a d.c.-to-a.c. power frequency device.

The breadth,B, and depth,D, of base **13** as well as the length, L, and spacing between the elements **11** and **12** enable the band width to which the elements **11** and **12** are responsive to be adjusted to provide optimum matching to the spectrum of the electromagnetic wave energy impinging on absorber elements **11** and **12**. Close spacing between adjacent elements **11** and **12**, in addition to enabling the electric field gradient to be coupled with the greatest voltage difference to terminals **21** and **22**, enables the electric field to be effectively trapped in the converging interstices between facing, adjacent elements **11** and **12**. Trapping of the electric field variations occurs because elements **11** and **12** are absorptive to the electric electromagnetic wave energy, whereby the energy is not reflected and re-radiated from the elements.

Because the device of FIG. **1** is responsive to a plane polarized electromagnetic wave, it is preferable for the depth, D, of each of the elements **11** and **12** to be relatively narrow, less than ¼ wave length, so that adjacent elements (not shown) can be packed as closely as possible to either side of elements **11** and **12** in the horizontal direction. Close packing of the elements enables maximum conversion of the electromagnetic wave energy into electric power over the entire area of an array which may be fabricated out of a multiplicity of element pairs as illustrated in FIG. **1**. It is to be noted that the device of FIG. **1** is responsive most efficiently to electromagnetic waves polarized so that the E field is in a plane parallel or coplanar with the long dimension of bases **13**. If the electromagnetic wave polarization direction were rotated 90°, there would be no substantial electric field variation between the adjacent elements **11** and **12** and there would be substantially zero

voltage developed between terminals **21** and **22** with a resulting zero conversion of electromagnetic wave energy into electric power.

The power of the electromagnetic wave incident on absorber elements **11** and **12** is the incident power density times the effective area of the two elements and can thereby be stated approximately as: 2 $(\overline{E}\times\overline{H})$ BD, where $\overline{E}$ and $\overline{H}$ are respectively the electric and magnetic fields of the wave energy. The power indicated by the equation is available so that it can be converted into electric power supplied to a load, except for losses in elements **11** and **12**, rectification, and stray losses. The losses of elements **11** and **12** are principally due to skin effect or di-electric losses, while the rectifier losses are the series resistance of the diode and stray losses are of the capacitor, and supporting substrate for elements **11** and **12.** Stray losses can be minimized by locating elements **11** and **12** on a low loss dielectric substrate to minimize loss currents between the abosrber terminals.

The maximum wavelength restriction (about 75λ of the longest wavelength of the received spectrum) is provided to enable the shortest wavelength of the desired spectrum to be trapped between adjacent elements and to provide a relatively large surface area for extracting power from it. If the maximum wavelength restriction, which corresponds approximately with the length of a cone in an eyeball of a mammal (about 75λ of the longest wavelength of the received spectrum), is exceeded by the incident electromagnetic energy spectrum, then the voltage output between terminals **21–22** of the device decreases.

If the device of FIG. **1** is utilized to convert plane polarized microwave electromagnetic wave energy into electric power, the rectifier circuit can be connected to the terminals by a coaxial cable having a center conductor connected directly to terminal **21** and a shielded outer conductor, possibly with a conventional balun, connected to terminal **22.** In the alternative, the rectifier circuit can be connected to elements **11** and **12** by a wave guide excited by the voltage difference between terminals **21** and **22** so that propagation in the wave guide is in one of the transverse electric modes, such as TE_{01}. In such a configuration, upper and lower conducting surfaces of a rectangular wave guide, between which the electric field is developed, are respectively connected to terminals **21** and **22.**

One microwave absorber actually constructed and tested in accordance with the present invention includes a pair of sheet copper pyramidal elements **11** and **12** having a length (L) of 13.3 centimeters, a breadth (B) of 6.3 centimeters, and a depth (D) of 2.0 centimeters. This absorber pair had a center frequency of approximately 475 Mhz and a pass band between approximately 200 and 700 Mhz. Increasing the length of the abosrber elements, without any changes in the base dimensions of the pyramid, lowered the pass band center frequency, as well as the upper and lower cut-off frequencies.

The basic converter structure of FIG. **1** can be modified, as illustrated in FIG. **2**, to respond to circularly polarized electromagnetic waves or randomly polarized electromagnetic waves, as subsist in solar energy. In FIG. **2**, a multiplicity of absorber elements **31** are arranged in a two-dimensional array of aligned orthogonally directed columns and rows. Elements **31** are mutually insulated from each other and mounted on a dielectric substrate **32**, which is preferably flexible but may be rigid. Each of elements **31** preferably has a symmetrical base and cross section parallel to the base, which may be either circular or square, to enable equal voltages to be derived between adjacent ones of elements **31** in the two orthogonal directions in response to orthogonal electric field components at the same wavelength. Thereby, the total array power output of FIG. **2** is insensitive to the polarization direction of the energy impinging thereon and the array can respond to circularly polarized, as well as randomly polarized electromagnetic wave energy.

To convert the electromagnetic wave energy impinging on elements **31** into electric power, adjacent elements are interconnected with each other by a half wave rectifying network similar to that illustrated in FIG. **1.** In particular, aligned vertical elements ***31a***, ***31b***, and ***31c*** are interconnected so that the anodes of rectifier diodes **33**, connected to elements ***31a*** and ***31c*** (which are separated from each other by element ***31b***) are connected directly to the elements, while the cathodes of the rectifier diodes are connected to one electrode of different capacitors **34**, the other electrodes which have a common connection to element ***31b***. Similarly, horizontally aligned elements ***31a***, ***31d***, and ***31e*** are connected to rectifier circuits such that the center element of the triad has a common connection to a pair of capacitors **34** which are connected to the cathodes of diodes **33**, having anodes connected to be responsive to the voltage replicas respectively derived by absorber element pairs ***31a–31d*** and ***31e–31d***. D. C. voltages developed across capacitors **34** are supplied to a matrix of load resistors **135**, one of which is connected across each of the capacitors.

Elements **31** of FIG. **2** are illustrated as frustoconical structures having upper bases with considerably smaller areas than the bases of the elements that are secured to substrate **32.** The frusto-conical configuration is preferred in certain instances because sharp points, as illustrated in the pyramidal elements **11** and **12**, FIG. **1**, may have a tendency to fracture.

To enable the structure illustrated in FIG. **2** to function as a device for converting solar electromagnetic wave energy, which has the majority of its power in the spectrum from 0.3 to 1.1 microns, into d.c. power, the element dimensions and inter-element spacing must be on the order of a micron, whereby integrated circuit techniques are preferably employed in fabrication. To this end, a solar energy converter in accordance with the present invention may take the form illustrated by the cross-sectional view illustrated in FIG. **3** but not limited to this embodiment. In FIG. **3**, electrically conductive cones ***31a***, ***31b***, and ***31c*** project from surface **35** of substrate **32.** Alternate ones of cones **31**, such as cones ***31a*** and ***31c***, are ohmically connected to a P-doped regions **36** of substrate **32**, which are formed on surface **35** of substrate **32** in super-position with the bases of cones ***31a*** and ***31c***. A junction is formed between P-doped regions **36** and N-doped regions **37** which are formed in substrate **32** beneath P-doped regions **36.** Regions **36** and **37** respectively correspond with the anode and cathode of diodes **33** connected to cones ***31a*** and ***31c***, FIG. **2.** Annular, dielectric oxide films **42** are formed on face **35** over the intersections between the otherwise exposed portions of the junctions between regions **36** and **37.** Oxide films **42** cover the peripheries of P-doped regions **36** and the inner circumference of N-doped regions **37.** On the portion of

P-doped regions **36** not covered by oxide films **42** and the inner radial portion of the films, metal elements **31***a* and **31***c* are placed. The bases of elements **31***a* and **31***c* are ohmically connected to P-doped regions **36**. Annular, metal films **38** are formed on face **35** in superposition with the otherwise exposed regions **37** to form ohmic contacts with the N-doped regions. Metal films **38** are electrically insulated from elements **31***a* and **31***c* by dielectric films **42** which are disposed between metal films and elements. Metal film **39** is formed on face **35** at the base of element **31***b* and is electrically connected to the base. The areas **41** of substrate **32** between adjacent metal films **38** and **39** form dielectrics for capacitors **34**, having electrodes comprised of the metal film portions **38** and **39**. A d.c. load is connected between metal film portions **38** and **39** so that the film portions form load terminals.

The structure of FIG. 3 is formed by diffusing P and N regions **36** and **37** onto surface **35** of substrate **32**, utilizing conventional integrated circuit techniques. Regions **36** and **37** are diffused only onto the areas beneath and slightly to the sides of where cones **31***a* and **31***d* are to be located. Thereafter, annular oxide regions **42** are formed over the exterior portion of P-doped region **36** and over a slight segment of the interior of N-doped region **37** on surface **35**. After oxide regions **42** have been formed, thin metal film contacts **38** are vacuum vapor deposited on the exposed portions of N regions **37**. Simultaneously with the formation of contacts **38** thin, metal film, annular contact **39** is vacuum vapor deposited on surface **35** in the region outside of cone **31***b*. After metal films **38** and **39** have been deposited, cones **31***a*, **31***b*, and **31***d* are suitably attached.

While metal is believed preferable in most instances for the absorber elements, it is to be understood that dielectric elements can also be utilized as elements for directing electromagnetic wave radiation to an optical to d.c. converter diode. The dielectric elements would preferably have the same configuration and dimensions as indicated supra while the optical to d.c. converter diode may be of a type described by Javin in the IEEE Spectrum, October, 1971, page 91.

While there have been described and illustrated several specific embodiments of the invention, it will be clear that variations in the details of the embodiments specifically illustrated and described may be made without departing from the true spirit and scope of the invention as defined in the appended claims.

I claim:

1. A device for converting electromagnetic wave energy having an electric field into electric power comprising a plurality of mutually insulated electromagnetic wave absorber elements each responsive to the electric field, adjacent ones of said elements converging toward each other in the direction of the wave propagation, each element including means for deriving a voltage replica of variations of the electric field intercepted by the element, adjacent ones of said elements being positioned relative to each other so that an electric field subsists between said adjacent elements, and means responsive to the voltage difference between the derived voltage replicas between two adjacent elements,

2. The device of claim **1** wherein each of the absorber elements is metallic.

3. The device of claim **1** where each of the absorber elements comprises a metallic surface and has a length in the direction of wave propagation several wavelengths of the impinging electromagnetic wave.

4. The device of claim **3** wherein the adjacent elements have substantially coplanar bases, and the spacing between the adjacent elements at the bases thereof is of the order of no more than a wavelength of the electromagnetic energy.

5. The device of claim **1** wherein the adjacent elements have substantially coplanar bases, and the spacing between the adjacent elements at the bases thereof is of the order of no more than a wavelength of the electromagnetic energy.

6. The device of claim **1** wherein the conversion means responsive to the voltage difference includes means for rectifying the voltage difference to derive a d.c. voltage.

7. A device for converting circularly polarized or randomly polarized electromagnetic wave energy having an electric field into electric power comprising a two-dimensional array of mutually insulated electromagnetic wave absorber elements each responsive to a component of the electric field, each elements converging toward each other in the direction of propagation of the wave and including means for deriving a voltage replica of variations of the electric field intercepted by the element, adjacent ones of said elements being positioned relative to each other so that an electric field subsists between said adjacent elements, and means responsive to the voltage difference between the voltage replicas derived between two adjacent elements, said pairs being spaced at right angles to each other in the array.

8. The device of claim **7** wherein each of the absorber elements is metallic.

9. The device of claim **7** where each of the absorber elements comprises a metallic surface and has a length in the direction of wave propagation several wavelengths of the electromagnetic wave.

10. The device of claim **9** wherein the adjacent elements have substantially co-planar bases and the spacing between the adjacent elements at the bases thereof of the order of one wavelength or less of the electromagnetic energy.

11. The device of claim **7** wherein the adjacent elements have substantially coplanar bases and the spacing between the adjacent elements at the bases thereof is of the order of one wavelength or less of the electromagnetic energy.

12. A device for converting solar, randomly polarized electromagnetic wave energy in the wave length band from approximately 0.3 to 1.1 microns into electric power comprising a dielectric substrate having a face substantially at right angles to the direction of propagation of the solar electromagnetic wave energy, a plurality of mutually insulated electromagnetic wave, metallic absorber elements mounted on said face, each of said elements including tapered portion extending away from the face in the direction of propagation of the wave energy, each of said elements having a decreasing cross-sectional area as the distance from the face increases and a length in the direction of propagation of the wave several wavelengths of the shortest wavelength of the spectrum, an integrated circuit diode in said substrate connected to be responsive to wave energy intercepted by alternately spaced ones of said

elements, a metallic film on said substrate ohmically connected to the remaining metallic elements, whereby a capacitor is formed in the substrate dielectric between adjacent ones of said metallic films.

13. The device of claim **12** wherein each of the elements includes a base with a symmetrical geometry in contact with said face, each element having a cross section parallel to the base similar to the base.

14. The device of claim **13** wherein said face has a square cross section.

15. The device of claim **13** wherein said face has a circular cross section.

16. The device of claim **13** wherein each of said elements is a frustum.

17. The device of claim **12** wherein the spacing between adjacent ones of said elements is of the order of one wavelength or less of the shortest wavelength of the spectrum.

18. The device of claim **12** wherein the several wavelengths are between 1.25 and 75.

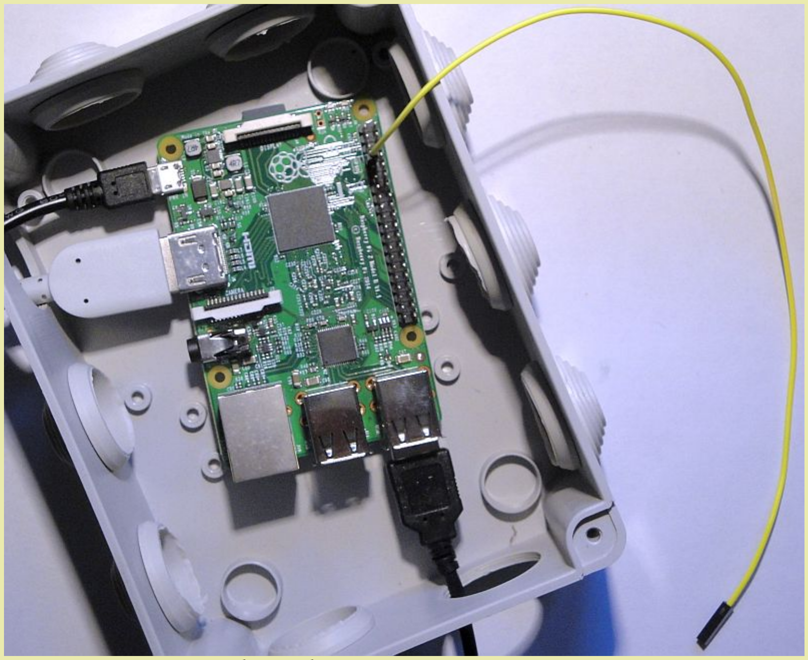
19. A device for converting solar, randomly polarized electromagnetic wave energy in the wave length band from approximately 0.3 to 1.1 microns into electric power comprising a dielectric substrate having a face substantially at right angles to the direction of propagation of the solar electromagnetic wave energy, a plurality of mutually insulated electromagnetic wave, metallic absorber elements mounted on said face, each of said elements including a tapered portion extending away from the face in the direction of propagation of the wave energy, each of said elements having a decreasing cross-sectional area as the distance from the face increases, adjacent ones of said elements being spaced from each other by a distance on the order of a wavelength or less of said energy, an integrated circuit diode in said substrate connected to be responsive to wave energy intercepted by alternately spaced ones of said elements, a first metallic film on said substrate ohmically connected to one electrode of each of said diodes, a second metallic film on said substrate ohmically connected to the remaining metallic elements, said first and second films including load terminals whereby a capacitor is formed in the substrate dielectric between adjacent ones of said metallic films, and said load terminals.

* * * * *

RF GENERATOR WITH THE RASPBERRY PI

2017

KLIK HIER VOOR DE NEDERLANDSE VERSIE



The Raspberry Pi in use as RF generator.
The yellow antenna wire is connected to the RF output GPIO_4 pin 7.

RF generator with the Raspberry Pi
The Raspberry Pi has a built-in clock oscillator that you can use as a RF generator!
Jan Panteltje (http://panteltje.com/) wrote a program for it that you can run in a terminal window. And so, you've got a simple RF generator with a frequency range of 240 kHz to 150 MHz. The clock oscillator itself goes up to 500 MHz, but the output ports of the Raspberry Pi are not suitable for those high frequencies. What the maximum frequency is, you have to try that. The output is on GPIO_4 pin 7.
The program also has a sweep generator function that I wanted to use to make frequency characteristics of my simple receivers. And with a small [adjustment], it was also possible to make AM and FM modulation with a 1 kHz test tone for adjusting receivers.
To run the program you have to type command lines in a terminal window:

Example for 1 MHz, with +39.4 parts per million correction :
freq_pi -f 100000000 -y 39.4

Example for a sweep from 1 MHz to 100 MHz step 1 MHz with 100 ms delay between steps:
freq_pi -b 1000000 -e 100000000 -i 1000000 -d 100000

Typing "command lines" in a terminal window is not really convenient. But it was not very difficult to make a simple GUI in Python. Jenny List G7CKF had made a similar program that I could use as an example. You can press buttons with the mouse and the program makes the correct "command lines" and sends it to the nice program of Jan Panteltje. This program was also modified a bit, so that you can make an FM or AM modulated burst of 20 seconds.

Installation
Create a new directory and copy the files in the following ZIP file to that directory:

- 17raspigensource.zip

Change the permissions of the script file "compile.sh" to execute "Anyone."
Click on the script file "compile.sh" and select "Execute in Terminal."
The file "freq_pi_oh1.c" will be compiled to the executable program "freq_pi_oh1". You will see this file appear in the directory.
For Python version 2, open in the menu: Programming --> Python 2 (IDLE) and open with it "Freq_piVFO-v01a_Python2.py"
For Python version 3, open in the menu: Programming --> Python 3 (IDLE) and open with it "Freq_piVFO-v01a_Python3.py"
Then choose "Run Module".

The Graphical User Interface that makes it easier to give the commands.

ON & OFF
Switches the RF generator on- and off.

SetStart & SetStop
Set the start- and stopfrequency of the sweep to the tuning frequency.

TimeStep- & TimeStep+
Set the time step of the sweep per frequency step, so it determines the sweep speed.

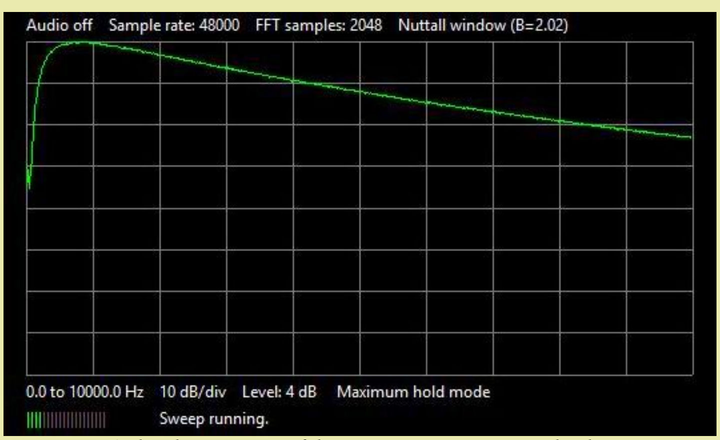
StartSweep
Starts the sweep.

Frequency- & Frequency+
Tuning.

FreqStep- & FreqStep+
Set the frequency stepsize of the tuning and also of the sweep.

AM & FM wide & FM narrow
Gives a modulated RF burst with a length of 20 seconds. After 20 seconds, the signal stops and you have to press the button again.

Measurements of the audio characteristics of receivers
Connect the audio output of the receiver with the soundcard of a PC with an audio spectrum analyser program.
For example: [11sa.htm](11sa.htm)
Program the frequency sweep as follows:
Start frequency at zero beat with the receiver (0 Hz audio tone)
Stopf requency: Startfrequency plus the audio range you want to measure.
Frequency step: 10 Hz
Time step: 100ms
Set the trace of the audio spectrum program to Max Hold and start the sweep, the trace will be drawn on the screen as shown below. If you want to compare two measurements, save the first measurement into the trace memory. Below you can see the wide bandwidth green colored. The orange colored narrow bandwidth has been measured first and is stored in the trace memory.



Audio characteristic of the regenerative receiver with tubes

Audio characteristic of the 80 meter CW transceiver
Green: Wide band CW characteristic
Orange: Narrow band CW characteristic

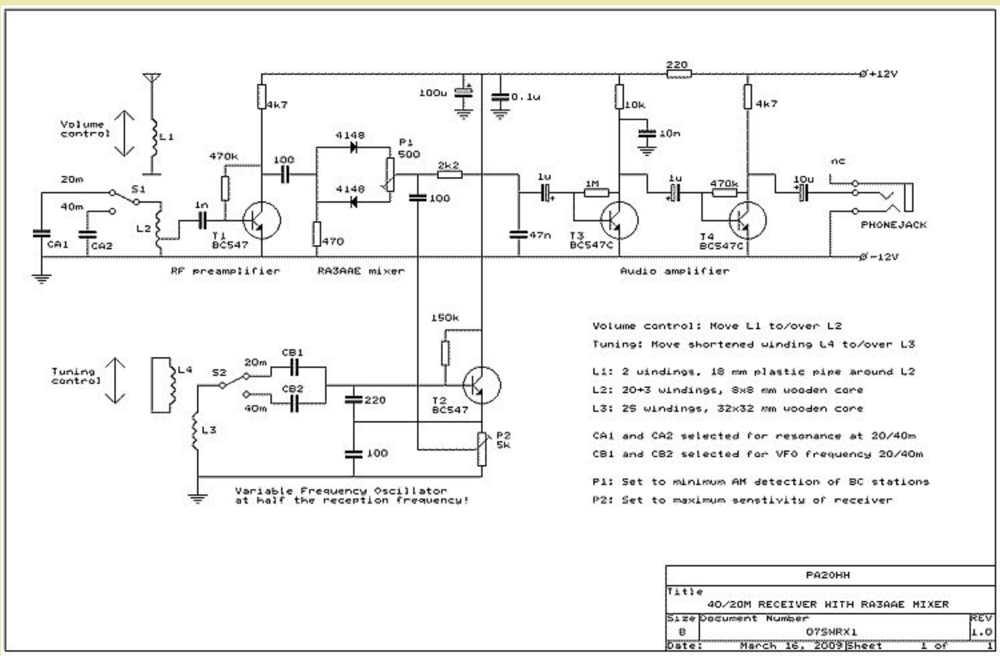
Measurements of the receiver for QRSS signals (weak slow-peed Morse code)
This measurement is equivalent to the "Receiver Audio Characteristics Measurements" as described above. When measuring the unwanted low sideband, the stop frequency is set to zero beat with the receiver (0 Hz audio tone) and the start frequency equal to the stop frequency minus the audio range you want to measure. The

desired sideband is the orange trace, the unwanted one is the green trace. The sideband suppression is the difference between both traces. The peak of the desired orange sideband and the unwanted green sideband dip should lie at the position of the red arrow. Could be better!

Bandwidth of the QRSS receiver

Sideband suppression of the QRSS receiver

Adjustment of the AM suppression of a direct conversion receiver
From the 30 meter QRP transceiver, the 500 ohm potentiometer in the receiving section has to be adjusted to maximum suppression of the detection of strong AM signals in the nearby broadcast band. The RF generator is AM modulated and tuned to a frequency in the middle of this band. The level is adjusted (positioning and adjusting the length of the antenna) that a clear signal is heard. Then the potentiometer is adjusted so that this signal is minimally audible.



The 500 ohm potentiometer of the direct conversion receiver has to be adjusted to maximum AM suppression.

Measurement of the sideband suppression of the 80 meter CW transceiver
Tune the RF generator to the desired sideband and measure the level. Then tune the RF generator to the unwanted sideband and measure the level again. The difference is the sideband suppression. It was exciting to measure that side band repression. Because 20 years ago, the receiver had to be adjusted quite accurately for a sideband suppression better than 40 dB. And ... After 20 years of use, it was still 41 dB!

How is the sideband suppression of the direct conversion receiver after 20 years of use?

SOFTWARE

Required Python version:

- Python version 2 or 3, these are already installed on the Raspberry Pi.

Changes to the program freq_pi_oh1.c
For the Raspberry Pi version 2b, a variable PLL0_FREQUENCY has to be changed to 1000000000.0 Hz. This can be done with the Geany editor with basic features of an integrated development environment. This variable was previously modified for other versions. If you want to change something yourself, do not forget to compile the program again!

```
int  mem_fd;
char *gpio_mem, *gpio_map;
char *spi0_mem, *spi0_map;
int wait_for_gpio8_flag;
double ppm_correction;
double pllo_frequency;


//#define PLL0_FREQUENCY 250000000.0
//#define PLL0_FREQUENCY 500000000.0
#define PLL0_FREQUENCY 1000000000.0

//Variables used by auto Pi model detection
static volatile uint32_t piModel = 1;
```

Changes to the program freq_pi_oh1.c can be done with the editor Geany with basic features of an integrated development environment.

The added code to generate an FM or AM burst
When the start frequency of the frequency sweep is higher than the stop frequency, the original program gives an error code. This error code has been changed to a code that gives an FM burst of 20 seconds. The RF frequency then toggles 1000x per second between both frequencies. And this code is also used for AM modulation! How? One of the frequencies is equal to the test frequency. The other is chosen so high that it is above the maximum range of the hardware of the output ports of the processor and also far outside the receiver's range. Simple and it works good!

```
if(end_frequency <= begin_frequency)
    {
    int n = 0;
    while(n < 20000)
        {
        set_frequency(begin_frequency);
        usleep(500);
        set_frequency(end_frequency);
        usleep(500);
        n = n + 1;
        }

    exit(0);
    }
```

The added code to generate an FM or AM burst.

BACK TO INDEX PA2OHH

MICROWAVE TO DC CONVERTER

Filed May 5, 1965

FIG. 1

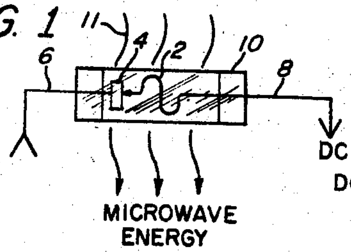


FIG. 2

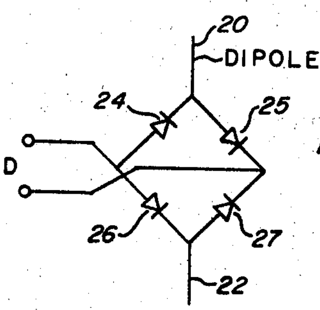


FIG. 3

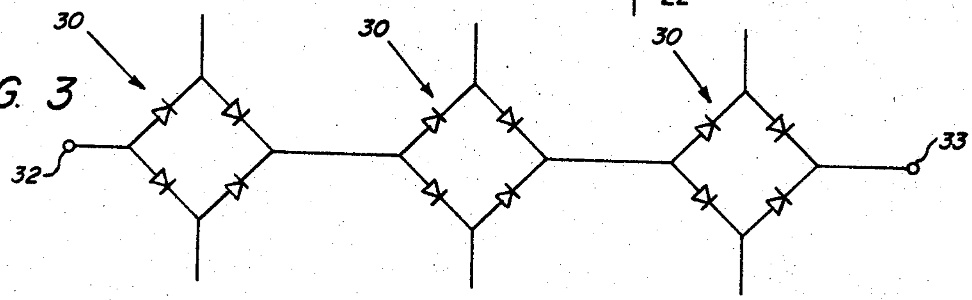
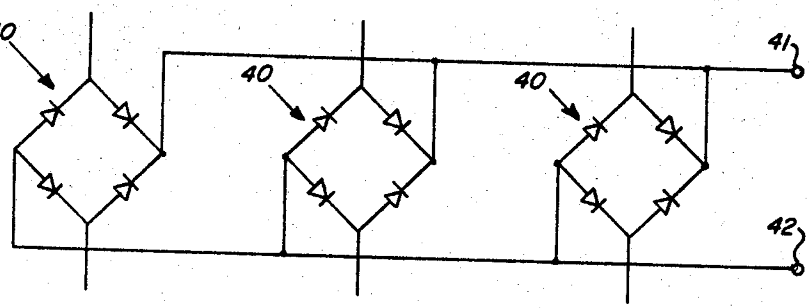


FIG. 4



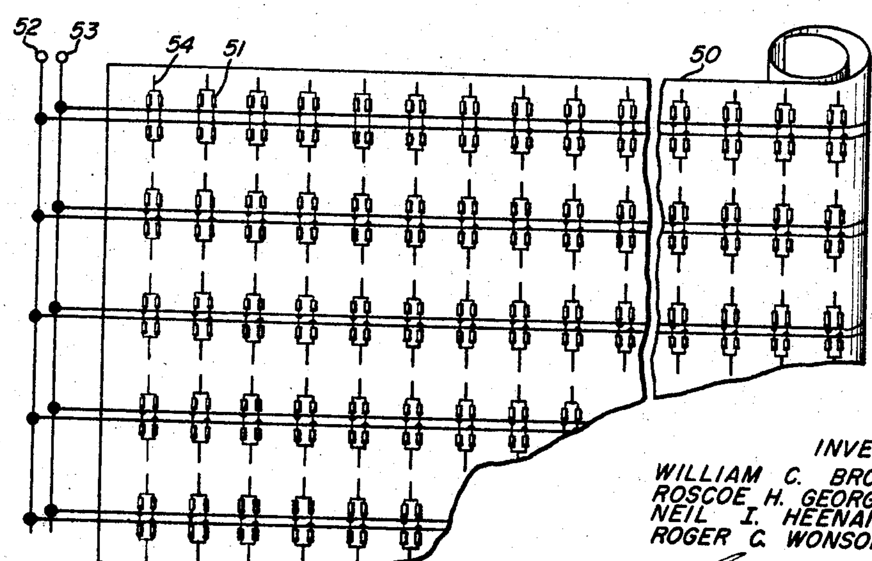


FIG. 5

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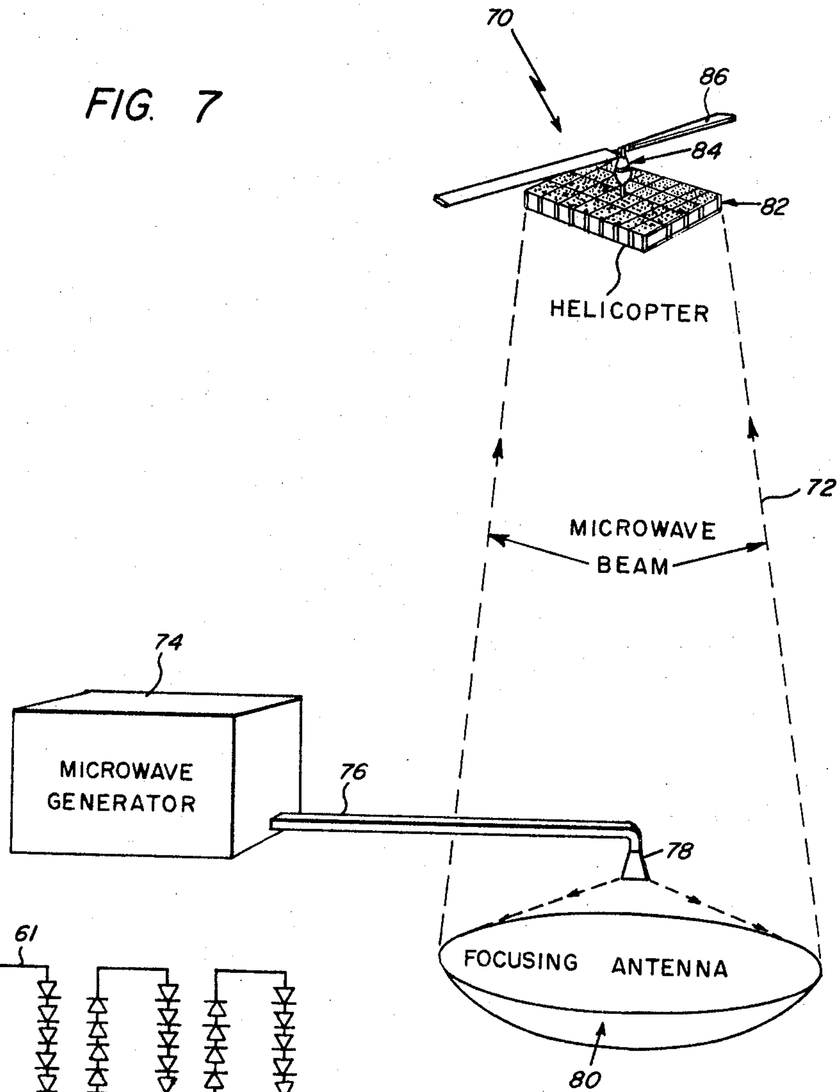
FIG. 7



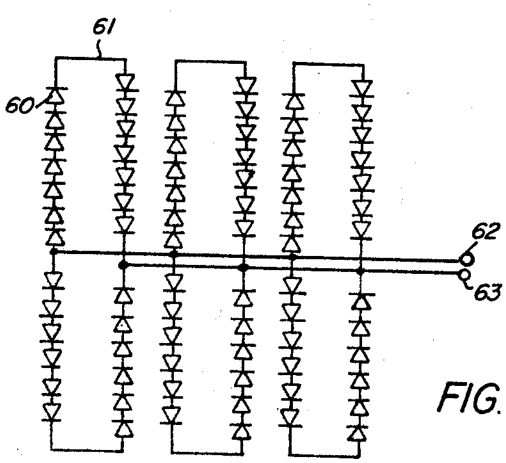


FIG. 6

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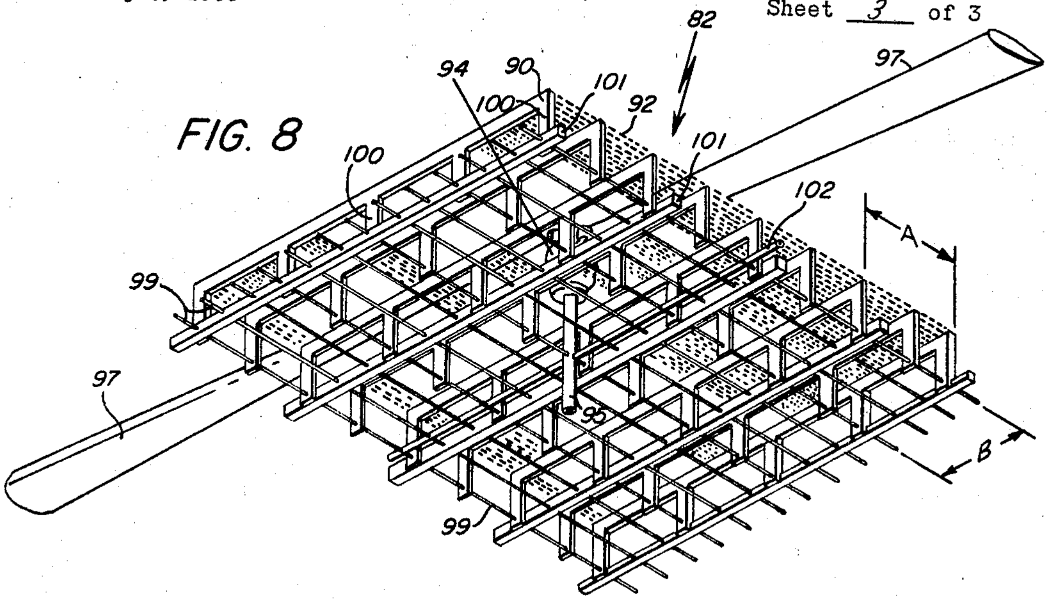

FIG. 8

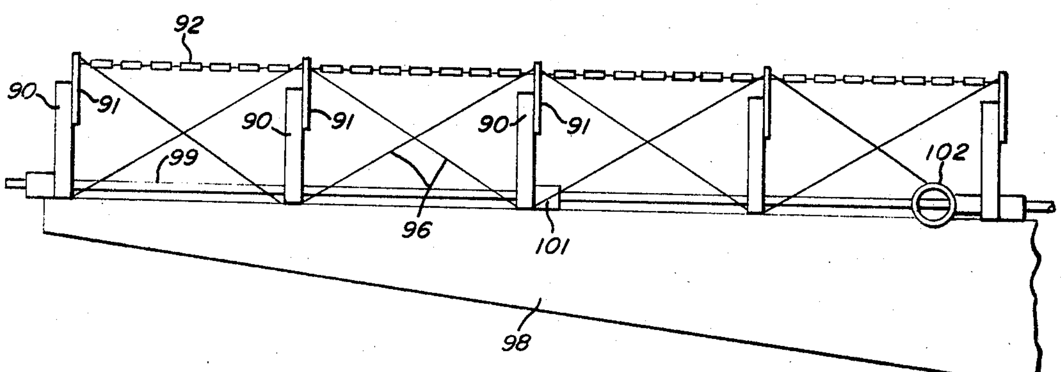

FIG. 9

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3,434,678

Patented Mar. 25, 1969

1

2

3,434,678

MICROWAVE TO DC CONVERTER

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Filed May 5, 1965, Ser. No. 453,415
Int. Cl. B64g *1/00*
U.S. Cl. 244—1 3 Claims

ABSTRACT OF THE DISCLOSURE

A combined antenna and conversion mechanism for reception of beamed high frequency electromagnetic energy in space including a large array of unidirectional current semiconductor rectifier devices. A self-supporting space vehicle utilizing the rectified DC electrical energy for propulsion is disclosed in an illustrative embodiment.

The present invention relates in general to the transfer of energy by means of an electromagnetic wave beam and more particularly to interception and rectification of such energy into low frequency electrical DC energy with a high degree of efficiency.

Improved technology in the field of microwave energy generation at superpower levels has resulted in the realization of electrical energy transmission over considerable distances for remote energization of devices or vehicles without the aid of wires. The transmission of microwave electromagnetic energy into space has been commonly employed in the radar pulse echo systems for the detection and orientation of desired objects within a predetermined scanning range of a transmitting antenna. Beams of a similar nature may now be employed for other useful purposes and the advantages attendant the utilization of electromagnetic energy in the microwave region in contrast with other wavelengths may now be enumerated.

Microwaves have been generally defined as high frequency radio waves whose wavelength is less than 30 centimeters, with a lower wavelength limit on the order of 1 millimeter sometimes being applied to what is commonly referred to as the "microwave region." The superiority of high frequency microwaves is due in part to the fact that it is generally desirable to focus the transmitted energy so as to achieve a high power density at a remote point or area with respect to a given power source. In accordance with the laws of optics, the sharpness of the microwave beam produced by a transmitting antenna varies as the ratio of antenna dimensions to the wavelength of the transmitted energy. Therefore, for a given or desired power density or beam sharpness, a decrease in the wavelength of the transmitted energy permits a corresponding decrease in the dimensions of the antenna. From the standpoint of mechanical considerations, it is desirable to employ small antennas and other components, and it is therefore advantageous to employ high frequency energy of very short wavelength. In addition, the difficulties encountered in long wave transmission as a result of natural and man-made interference or noise do not occur with any appreciable significance at microwave frequencies. Further, in aerospace applications with considerable distances separating the transmitter at an earth or mother planet location and the employment of shorter wavelength beamed energy is preferred since longer wave signals will generallly be reflected at certain altitudes by reflecting layers in the atmosphere.

In view of certain losses due to absorption which may occur in the atmosphere, microwaves in the region having the approximate bounds of 2 and 30 centimeters are readily adaptable to the convenient radiation of power to remote points without the utilization of wires. The preferred wavelengths are of the order of 5 or 10 centimeters to provide efficient focusing with existing transmitting antenna systems which may be maintained at a reasonable size. An illustrative device of the superpower high frequency microwave generators operative in the desired band is the so-called Amplitron which is an amplifier having a broad bandwidth and excellent performance characteristics for the focusing of the beam. Such devices are capable of producing 15 or 20 kilowatts of average continuous wave power in the neighborhood of 10 centimeters in wavelength with capabilities expected in the region of 500 kilowatts or more average power with 50 megawatts peak power. A complete description of such devices may be had by referring to Patent No. 2,933,723 issued Apr. 19, 1960 to William C. Brown and assigned to the assignee of the present invention.

With microwave energy capable of being generated and directed over longer distances conversion of such high frequency electromagnetic energy is of paramount concern. One conversion mechanism in the prior art involves direct conversion of such energy into heat which may then be utilized directly or indirectly for propulsion or generation of flight-producing forces. Examples of such devices for heat energy exchange as well as space vehicles utilizing such energy may be noted in Patent No. 3,174,-705, issued Mar. 23, 1965, to D. Schiff et al., as well as U.S. Letters Patent No. 3,083,528, issued Apr. 2, 1963 and No. 3,114,517, issued Dec. 17, 1963, to William C. Brown. The heat exchanger method of conversion of electromagnetic energy into useful power is limited by the overall efficiencies of approximately 25 percent in the conversion of heat into mechanical or electrical work. Desirable, therefore, would be the direct rectification of the high frequency electromagnetic energy into low frequency electrical energy for the operation of many useful aerospace devices as well as systems.

The present invention has for its primary object the conversion of high frequency electromagnetic energy in the microwave region directly into low frequency electrical energy.

A further object of the present invention is the provision of a combined nondirectional receiving antenna and microwave electromagnetic energy to low frequency electrical energy conversion means in a unitary structure.

A still further object of the present invention is a provision of a new and novel combined nondirectional receiving antenna and microwave to DC energy converter for aerospace applications.

Another object of the present invention is the provision of a new and novel nondirectional receiving antenna and microwave to DC energy converter having a high degree of efficiency.

Still another object of the present invention is the provision of a new and novel aerospace vehicle with nondirectional receiving antenna and microwave to DC energy converter means with said vehicle being capable of being supported by its own energy generation means at a distance spaced apart from the power generation means.

In accordance with the teachings of the present invention, the above and other objects are achieved by the employment of efficient unidirectional microwave power rectifiers and dipole antenna means. Such rectifying devices, while being individually limited in power-handling capabilities, normally in the order of fractions of watts, have been found to be highly efficient means for the rectification of microwave power when assembled in large numbers in various arrays. It is interesting to note that the observed collective efficiency was on the order of 40 to 70 percent. In an illustrative embodiment, point-

contact semiconductor diodes were arranged in four arm bridge connected networks with the networks interconnected in various configurations such as series, parallel and series-parallel.

In discussing aerospace applications, an additional problem is encountered in the beaming of microwave energy to a remote point and the interception and utilization of such electrical energy. In such applications the advantages of a vehicle which may be maintained in space for indeterminate periods of time without employing a local fuel source are readily apparent. Such devices could readily provide communication networks, surveillance functions using radar techniques along with numerous other functions. The acapture of the beamed high frequency electromagnetic energy raises the need for an efficient antenna means capable of intersecting the beam at high altitudes. Conventional techniques employed in microwave radar usage such as receiving antenna horns are capable of intersecting only a small portion of the beam energy and add considerable weight in applications involving heavier-than-air vehicles. In an exemplary embodiment of the invention a space vehicle, namely a helicopter, is disclosed for either moving flight or a stationary location with self-supporting electrically operative propulsion means. The semi-conductor diode rectifier arrays have been demonstrated to fulfill the receiving antenna functions as well as the electrical energy rectification means in a highly efficient manner. Such combined antenna and rectifier means has also assisted in reduction of the weight problem in airborne devices. Further, it has provided a nondirectional means for the interception of the microwave energy to thereby reduce the problems of focusing inherent in prior art directional horn type receiving antennas.

With the above features, advantages and objects in mind the invention will now be described by reference to the following detailed description together with the accompanying drawings in which:

FIG. 1 is a perspective view of an illustrative diode rectifier;

FIG. 2 is a schematic circuit diagram of a bridge connected diode network with dipole antenna means;

FIG. 3 is a schematic circuit diagram of a plurality of bridge connected networks arranged in series;

FIG. 4 is a schematic circuit diagram of a parallel bridge connected network array;

FIG. 5 is a perspective view of an illustrative embodiment of a combined antenna and rectifier array in a folded or rolled up configuration;

FIG. 6 is a schematic circuit diagram illustrating the bridge connected diode array incorporated in the aerospace vehicle shown in FIG. 7;

FIG. 7 is a schematic representation in elevation illustrative of a heavier-than-air aerospace vehicle incorparating the structure of the present invention;

FIG. 8 is a perspective view of the aerospace vehicle embodiment as viewed from the under portion thereof; and

FIG. 9 is an enlarged partial view in elevation of a portion of the illustrative embodiment shown in FIG. 8.

FIG. 1 illustrates a point-contact semiconductor diode rectifier of the type employed in radar microwave receiver apparatus to rectify returned radar pulses. Any of the high burnout semiconductor diodes having high rectification characteristics are preferred and are commercially available, such as the 1N82 or 1N830. The rectifying junction is formed by whisker element **2** contacting the semiconductor element **4** respectively connected to leads **6** and **8**. Silicon is preferred over germanium for element **4** because of its ability to operate at higher temperatures and thereby handle higher powers. Envelope **10** houses the rectifying elements and may be of a hermetically sealed dielectric material or combination metal and ceramic composition. The inherent characteristic of such diode rectifiers is that the microwave energy is intercepted and rectified in a unidirectional manner and the line **11** indicate pictorially the rays of the beamed electromagnetic microwave energy in a plane normal to the envelope. In FIG. 2 a full-wave bridge connected diode network is illustrated with the forward direction of the rectified DC electric current indicated by the direction of the arrow symbols. The network shown consists of half-wave dipoles **20** and **22** each terminated with a diode rectifier element **24** to **27** in an arm of the bridge connected network. The dipole elements **20** and **22** are of the half-wave configuration and may be spaced apart from each other a one-half wavelength at the frequency of the beamed electromagnetic energy.

Referring now to FIG. 3, an array of bridge connected diode networks each with the half-wave dipoles are shown connected in series. Each network is referred to by the numeral **30** and is similar in the bridge connections to the single element network shown in FIG. 2. The DC output of the collective rectified energy is coupled by means of terminals **32** and **33**. In FIG. 4, a similar number of individual bridge connected diode-dipole networks are shown connected in a parallel array. Each network is indicated by the numeral **40**, and the output terminals are indicated as **41** and **42**.

Any number of diode-dipole networks may be provided and in FIG. 5 such a multi-element array is illustrated by mounting on a flexible material **50** which may be rolled or folded into any desired package or enclosed within a capsule to be launched and released at a predetermined point in space. Any flexible material which is pervious to electromagnetic energy is preferred. The total power desired would be the determining factor in a number of individual diode-dipole elements required. In this embodiment, the bridge connected networks **51** are connected in parallel to the output load indicated by terminals **52** and **53**, and representative measurements of electrical characteristics have shown that approximately five watts of DC electrical energy is realizable for each square foot of area of the combined antenna-rectifier. While the dipole elements **54** have been indicated in a particular array, it is within the scope of the invention to stagger the placement of such dipoles to increase the over-all efficiency of the antenna-rectifier.

To further increase the DC powder output, the full-wave bridge connected networks are preferably arranged with a plurality of diodes in series in each arm of the bridge. An illustrative schematic circuit diagram of such a configuration is shown in FIG. 6 wherein seven diodes **60** are shown in each arm of the bridge circuit and are connected in series for a total of twenty-eight diodes in each bridge network. The dipole members will then be the substantially U-shaped end portions **61** at the ends of each brace of seven diodes. In the illustration three such twenty-eight diode bridge networks are shown connected in parallel to terminals **62** and **63**. This closer spacing and compact arrangement has been shown to be a source of improved power output and is capable of a high degree of reliability through the redundant nature of the parallel series connections within each bridge network. If one of the diode rectifiers fails to function the over-all voltage drop across this element would be divided among the six remaining diode rectifiers. If any of the connecting wires between the diode elements should break, the adjacent arms of the other bridge assemblies would take the additional load due to the close proximity of the respective arms to each other. In addition, it is possible to have a number of open connections or inoperative diodes dispersed throughout the array without any serious impairment in performance.

In relation to the array concept to be hereinafter described it may be stated that within a six inch square area ten such individual bridge networks each containing twenty-eight diode rectifiers for a total of 280 diode rectifiers may be deployed in such a manner as to provide

maximum exposed area for each diode as well as the connecting leads. Such an arrangement will be hereinafter referred to as a "module" and a DC output in excess of fourteen watts has been measured for such a module. Any number of such modules could be connected provided for a desired power yield and this module concept readily lends itself to use in certain aerospace applications now to be described.

In FIG. 7 a propelled type of space vehicle **70** is shown wholly supported by means of the transfer and rectification of continuous wave electromagnetic energy via a microwave beam **72**. The source of the microwave energy which may be of the Amplitron type device as described in the aforementioned issued Patent No. 2,933,723 is indicated as **74**. This energy is fed by waveguide means **76** to a transmitting horn **78** to illuminate an ellipsoidal beam forming focusing antenna **80** for the transmission of the microwave beam **72**. It will be appreciated by those skilled in the art that the representations of the microwave generation and transmitting antenna means are pictorial representations to illustrate the usage of the invention in diagrammatic form and the present invention is not limited to any particular source of microwave energy or transmitting antenna assembly. It may be stated the reflector of the antenna assembly is considerably larger than most of the reflectors of the prior art in order to focus a large amount of the microwave power at high altitudes for use in the transfer of energy to space vehicles. Such antenna assemblies may be partially supported in a large hollowed area on the earth's surface or other convenient means of support.

The space vehicle or helicopter **70** can be described as a main body member supporting antenna-rectifier means **82** including a large number of the so-called modules connected together and rigidly supported in a planar parallel array. A motor **84** is supported by the combined body member and the receiving antenna-rectifier means and actuates the rotor **86** of conventional design employed in such self-propelled hovering vehicles. The disclosed vehicle provides for the illumination of the planar array of the semiconductor diode dipole elements by the microwave beam and the direct conversion of the microwave power transmitted by the beam into usable electrical energy for the self-propulsion of the device without any local fuel supply being required.

FIGS. 8 and 9 illustrate a space vehicle **82** comprising a plurality of the combined receiving antenna-rectifier module means for interception and rectification of the electromagnetic microwave energy beam emanating from an earth or mother planet source. A planar array of the antenna-rectifier modules is mechanically supported by means of structural members **90** of any lightweight wood or metal. Insulators **91** positioned coextensive with the members **90** support the diode rectifier array and avoid interference with the receiving and electrical performance characteristics by the structural support members. Carrying forward the module concept of 280 diode rectifiers to provide an approximate power output of 14 watts, it was noted that any number of such modules may be coupled together since the individual module outputs are relatively insensitive to a wide range of load resistances connected to the common output terminals. To achieve the desired electrical output of approximately 120 volts and 250 watts of power, subgroups of four modules each were assembled and parallel connected with an approximate 30 volts available for each subgroup. Four such subgroups were series-connected to result in a total of 4,480 diode rectifiers or 16 modules assembled in a two foot square self-supporting planar parallel array structure. The individual diode rectifiers connected in each arm of the bridge network are indicated by the numeral **92**. An exemplary module configuration would extend within the area delineated by the dotted lines and reference letter A on one side and similar dotted lines and reference letter B on the other side.

A motor **94** is connected to the DC side of the overall array and may be additionally supported by tubular member **95**. A shaft and propulsion means consisting of rotor blades **97** provide for the upward lift of the overall vehicle for the self-supporting of same in space applications. Additional structural support such as interlaced rigging **96** of a high tensile strength material such as nylon or steel wire, as well as bracing member **98**, may be employed for strengthening of the body means to withstand the vibrational forces and downwash from the propulsion means.

In accordance with the well known technology of microwave transmission the combined array of diode rectifiers and propulsion means presents a specific load impedance which must be suitably matched to the transmitted microwave energy beam to result in maximum efficiency. In aerospace applications a mismatch of approximately ten to one may be evident. Matching of the load impedance to a value of approximately 377 ohms as the free space value will be provided by a plurality of coplanar parallel metallic rod members **99** disposed in a grating array in front of the diode rectifiers a predetermined distance. Rod members **99** are linearly disposed and extend in a similar direction as the assembled diode rectifiers. A selected frontal spacing of one-quarter of the wavelength of the microwave frequency being transmitted has been experimentally determined to be suitable for impedance matching purposes. An approximate spacing of two inches between the respective members was preferred for a selected microwave frequency of 2,450 megacycles. Each of the members **90** are provided with lateral sections **100** to support the elongated bar members **101** which in turn maintain the rod members **99** in the desired position. A tubular member **102** of a lightweight metal may also be provided to combine with the motor support member **95** for structural support.

The combined antenna-rectifier array provides a source of electrical energy to render any space vehicle self-supporting. The diode rectifier elements when assembled in the antenna array have been found to be nondirectional with respect to interception of the beamed microwave energy. This represents a large step forward in the utilization of high power microwave energy over the prior art horn-type receiving antennas which must be accurately focused and pointed in a particular direction for the reception of any energy. The connections between the respective members of the diode rectifier array and deployment in the parallel configuration serves to provide maximum exposed area. Such connections and in particular the end loop portions adjacent the terminus of each arm of the bridge networks serves as an efficient dipole for the interception of the microwave energy.

Although it is not intended as a full explanation of the high degree of efficiency attained with the disclosed antenna-rectifier array, it is believed that the whisker elements within the semiconductor diodes themselves are a contributing factor and may function as additional dipole elements. The disclosed embodiment functioned efficiently when illuminated by microwave energy generating a vertically polarized beam. Hence, an efficient and light weight energy conversion apparatus is disclosed which may be self-supporting without the requirement of a large local fuel supply payload.

It may be within the purview of the invention to use the available rectified electrical energy for performing many functions in addition to the actuation of the propulsion means. Hence, communications' payloads may be maintained at predetermined positions in space in a hovering attitude utilizing a portion of the electrical energy available. Relay signals to other such vehicles or return signals to ground stations would then be within the realm of possibility. Such available energy may also be employed for servomechanisms, stabilizing and countertorque systems for the navigation of such vehicles.

The electrical efficiencies realized with the combined

receiving antenna and rectifier means have also provided certain weight advantages over other energy converters in aerospace applications. Examples of such converters would be heat exchangers or solar cells. In comparison to the present invention where five to eight pounds per kilowatt of energy realized is a normal characteristic, other energy conversion means weigh in the vicinity of 150 pounds per kilowatt of realizable energy. The inherent advantages of the present invention are therefore apparent. While the technology in the diode rectifier art is being continually advanced, new diode power rectifiers as well as integrated circuit techniques are readily available to future configurations of the present invention. The so-called Schottky barrier diodes could be employed to produce combined antenna-rectifier means weighing even less than two pounds per kilowatt of available energy.

Although the foregoing detailed description has referred to DC power rectification it will be evident that with suitable circuit components low frequency AC energy may also be made available. In addition, other propulsion means may be readily substituted using electrical energy. The embodiments disclosed herein are illustrative only and other modifications or alterations will be apparent to those skilled in the art which do not depart from the scope of the broadest aspects of the present invention as defined in the appended claims.

What is claimed is:

1. A space vehicle comprising:

body means;

said body means including spaced structural support members;

combined antenna and DC electrical energy rectification means for the interception and rectification of incident high frequency electromagnetic microwave energy carried by said support members in a planar parallel array;

said rectification means comprising a plurality of four arm full-wave bridge connected rectifier circuit networks each having a plurality of unidirectional semiconductors in each arm;

said networks being electrically interconnected to common output terminals;

electrically operable propulsion means comprising a motor and rotor members carried by said body means and connected to said terminals for the utilization of said rectified DC energy; and

means for matching the load impedance of said combined antenna and electrical energy rectification means to the incident microwave energy.

2. A space vehicle according to claim 1 wherein said load impedance matching means are arranged in a coplanar array coextensive with said antenna and energy rectification means array, and spaced therefrom a distance of approximately one-quarter of a wavelength at the frequency of the microwave energy.

3. A space vehicle according to claim 2 wherein said load impedance matching means comprise a plurality of parallel disposed elongated metallic members.

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307—151; 318—16; 321—27; 325—494; 343—100

MDS975 www.mds975.co.uk

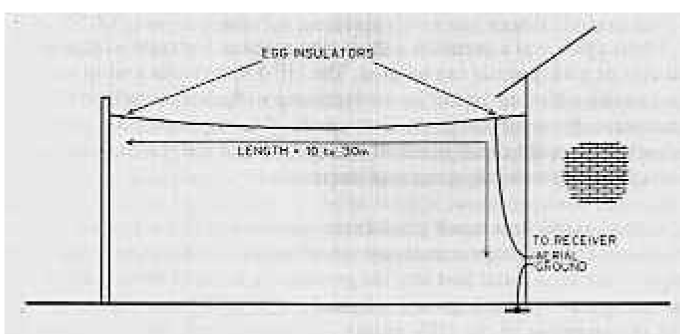
ANTENNA TUNING UNITS (ATUs)

ATUs - ANTENNA TUNING UNITS

THE ATU

An Antenna Tuning Unit

For good Short Wave reception long aerial really is required to dig those distant stations out of the ether. To effectively couple such an aerial to a radio a matching unit called an ATU (Antenna Tuning Unit) can often be extremely helpful. An ATU is relatively straightforward to construct and uses simple parts that are quite easy to obtain. The ATU shown above is of my own construction and is used with a Lowe [HF-150](#) receiver.



Typical Aerial Installation

AERIALS [or ANTENNAS]

AERIAL n. & adj. > n. a metal rod, wire or other structure by which signals are transmitted or received as part of a radio or television transmission or receiving system. > adj. 1. by or from or involving aircraft (aerial navigation; aerial photography). > 2 a existing, moving or happening in the air. b of or in the atmosphere, atmospheric. 3 a thin as air, ethereal. b immaterial, imaginary. c of air, gaseous

For the purpose of this page we'll choose the noun, I think. So the aerial can be:

A Random Length Of Wire Strung As High As Possible
OR -
A Carefully Designed Structure Whereby The Element (Or Elements) Is (Are) Tuned To Resonate At The Required Operating Wavelength (Frequency) Of The Station Or Waveband Being Received

(What??)

The advantage of a long random wire aerial to a listener is that it is easy to install in a loft or around a garden. Many Short Wave Listeners' (SWL's) aerials consist of such a long end fed wire of a random length perhaps between 10 and 50 meters, i.e. not cut to resonate at a specific wavelength. The disadvantage is that it is not tuned to a specific wavelength and therfore may not be particularly efficient at gathering the signals from a desired station. This is because a random wire aerial system will not present an even impedance* to the input of the radio receiver. This should generally be around 50 Ohms.

[* Impedance is the resistance to the flow of an alternating current (AC) - in this case a radio wave]

The impedance of a random wire aerial could swing from a few Ohms up to several thousand Ohms depending on what frequency is being used. This will present a serious mis-match to the receiver, which would prefer to 'see' a nice constant 50 Ohm load. This mismatch of impedance between aerial and radio can detrimentally effect the amount of signal transferred from the aerial to the radio, and therfore weaken reception of stations at some wavelengths.

An Antenna Tuning Unit (ATU) can help match the impedance of the aerial to the 50 Ohm impedance required by the radio. Once the impedance of the aerial matches the impedance at the input of the radio (after being tuned by the ATU) the greater the chance of the RF energy being effectively transferred.

Using an ATU will not always improve reception. If, by pure chance, the random wire aerial presents a 50 Ohm impedance to the radio on, say, the 41 meter band then no further improvement in signal strength will be obtained. But then if the radio is tuned to the 25 meter band, for instance, the aerial may have a 500 Ohm impedance and on this band the ATU will help to transfer more signal and improve reception.

WAVELENGTHS AND FREQUENCIES

This is the mathematical formula to calculate the wavelength of a particular frequency:

V/F = wavelength

E.G: V/F = 300,000,000/1,875,000Hz = 300/1.875MHz = 160m

The velocity of a radio wave when travelling through space is the same as the spped of light

i.e. 300,000,000 meters per second (186,000 miles per second). V = Velocity, F = Frequency in Hz. The result of the calculation is the wavelength in meters.

Once the wavelength of the radio wave is known, the relationship with the length of the aerial can be determined. An aerial that is 1/4 wavelength or an odd multiple of 1/4 wavelengths e.g. 5/8th or 7/8th wavelength, the impedance presented to the receiver will be quite low. If the aerial is a full or half wavelength long then the impedance will be much higher.

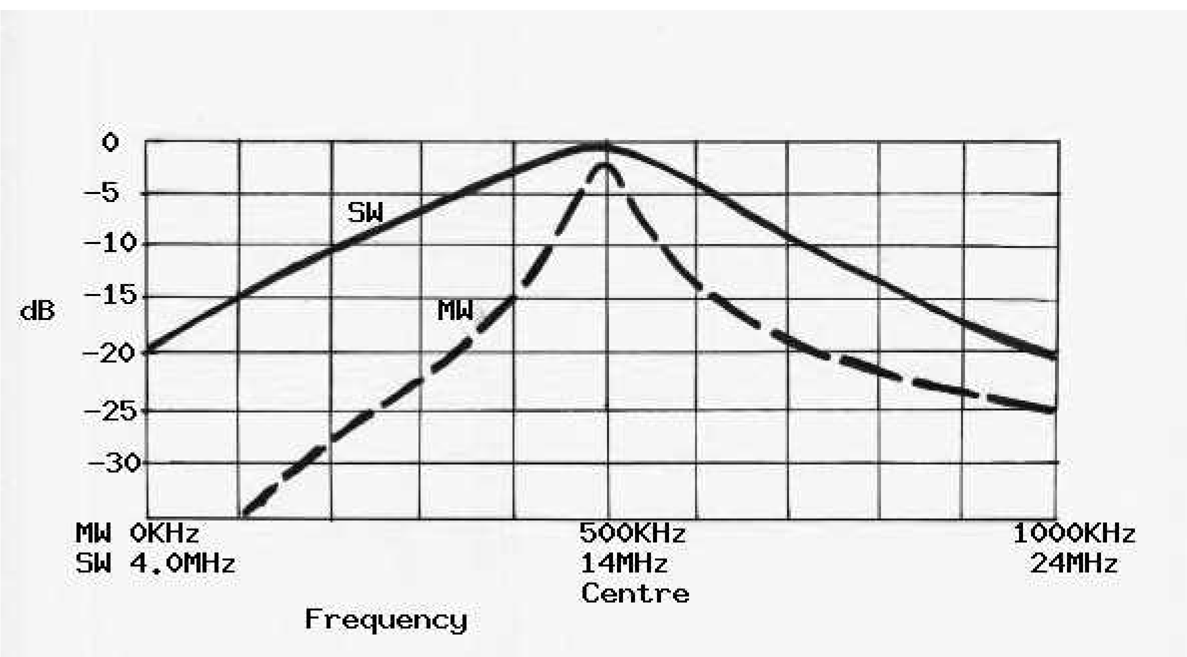
LOWE, JOHN WILSON AND THE SIX BAND SAGGER

Have a little look at the bottom of the LOWE HF-150 page since it includes an interesting article by John Wilson, formerly of Lowe Electronics, about aerials, specifically the "Six Band Sagger".

ATUs AND FILTERING

The ATU acts as an Impedance Matching Transformer with the ability to accept a wide range of input impedances and match them to the 50ohms that is required by the receiver. It also has the bonus of providing an certain amount of filtering, which can help overcome receiver overloading, by letting through the required frequency while attenuating the higher and lower frequencies. There are two types of ATU circuits described further down this page, the Pi type and the T type. The T type is particularly effective as a 'high pass' filter, and is very useful for filtering out interference on Short Wave caused by high power Medium Wave transmitters that can overload a short wave radio.

The graph below shows the effect that can be acheived:

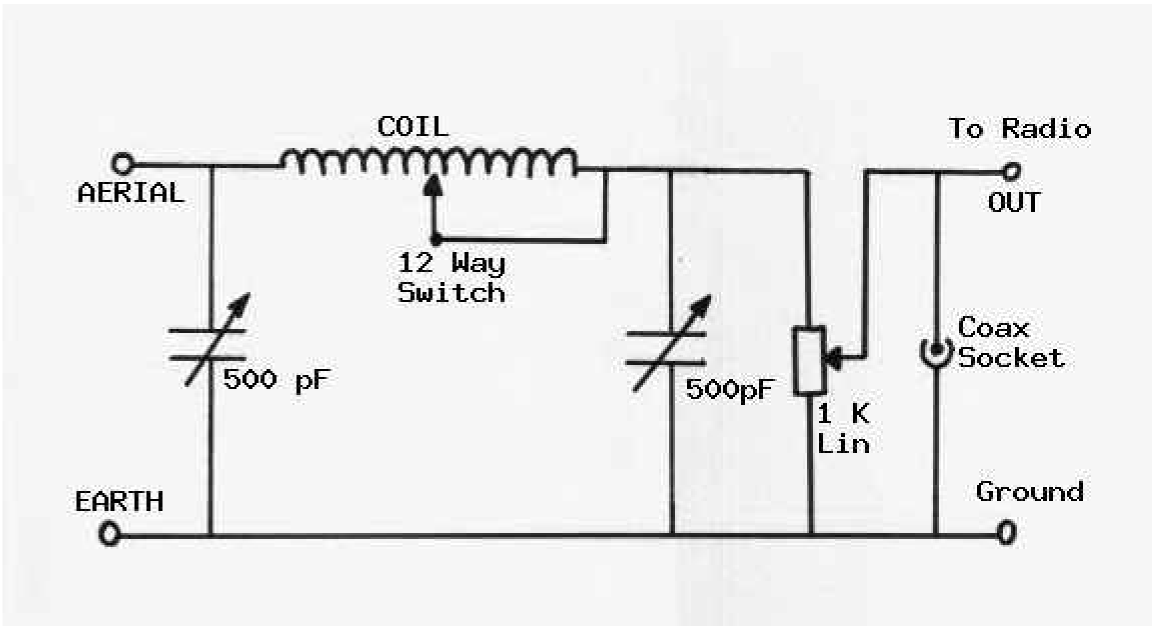


The solid line shows the filtering effect of an ATU at shortwave frequencies, while the broken line shows the filtering performance at medium wave frequencies

MAKE YOUR OWN ATU

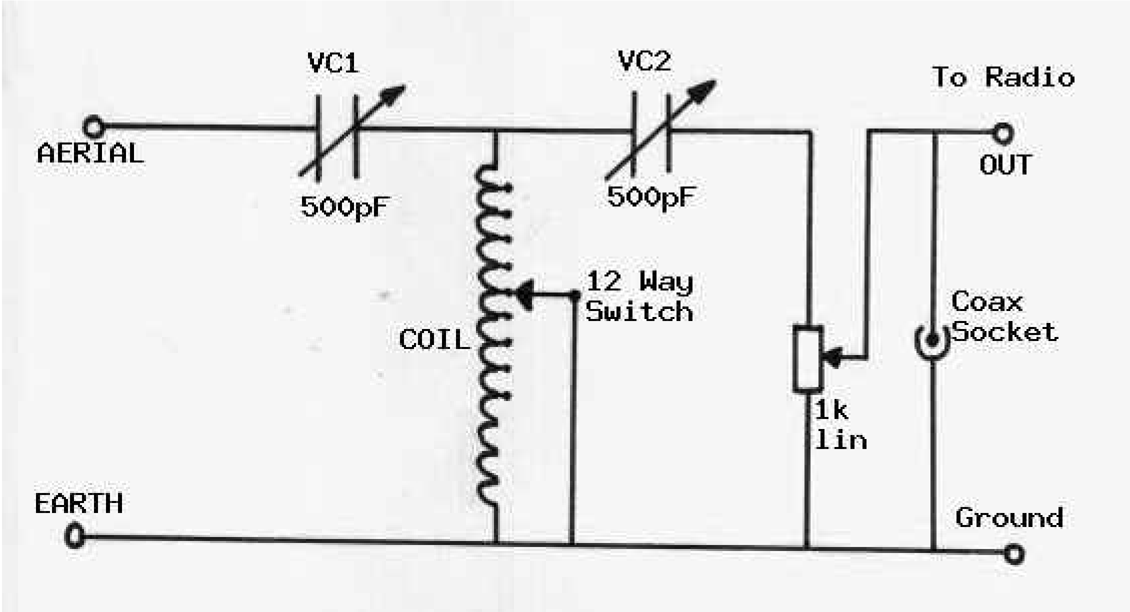
The circuit diagram below shows the circuit for a typical Pi type ATU which seems to be a popular arrange ment for many ATUs. I have built ATUs using this Pi arrangement and although they work quite well and are certainly a useful improvement over no ATU at all, I have found in my own experience that the 'T' arrangement in the next circuit works even better, matching more easily over a wide range of frequencies and also seemingly offering improved filtering in my own circumstances.

Each aerial arrangement is different and you may find that this circuit performs best of all in your circumstances:



Pi type circuit - Very popular for many ATUs

Below is the circuit diagram for my preferred choice of a T type circuit which includes a variable attenuator and which could not be simpler to construct. This circuit, with the coil described, covers from 500kHz medium wave to 30MHz short wave. Tuning capacitor VC1 is adjusted to match the aerial side while tuning capacitor VC2 is adjusted to match the receiver side. This circuit is often referred to as a TRANSMATCH, particularly in the USA.



T type circuit, which I have found to be more effective than the Pi type at my listening post, possibly because this design acts as a 'high pass' filter, and is therefore very useful for filtering out interference to short wave reception caused by high power medium wave transmitters that can overload the short wave radio

All that is needed is:

1	Self wound coil with 12 tapping points. See below
1	Reel of 22 s.w.g enamelled copper wire for coil
1	Coil former, eg the inside of a fax roll (30 mm diam approx)
1	12 way switch to select tapping pints on coil
2	500pF tuning capacitors (200pF or 365pF can also be used)
1	1 k ohm linear potentiometer for attenuator
2	Red terminal posts
2	Green terminal posts
1	Coaxial socket, e.g. 3.5mm jack (as used here) or SO239
1	Case 150 x 100 x 60 mm + with rubber feet

See additional notes below >

SOURCES FOR TUNING CAPACITORS

Old broken radio sets - but don't smash a nice one up for the sake of a capacitor! Old radio sets, especially the old 'valved' wirelesses are very interesting and often sound superb and could be quite rare.

J BIRKETT RADIO COMPONENTS,. 25 THE STRAIT, LINCOLN, LN2 1JD. telephone (uk) 01522 520767 http://www.zyra.org.uk/birkett.htm

MAINLINE GROUP http://www.mainlinegroup.co.uk/jacksonbrothers/index.htm

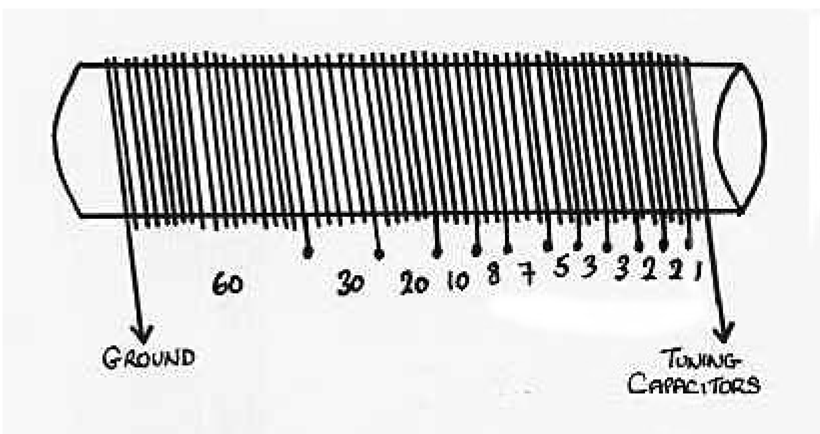
COIL WINDING DETAILS

The coils that I have made for my ATUs have been wound around formers made from the plasic tube found inside a typical fax roll. This can be cut to a suitable length to fit inside the enclosure, in this case 150mm long with a 30mm diameter. If a plastic fax roll is not available then a strong cardboard tube could be used instead.

Two small holes can be drilled at each end of the tube to feed the start and finish portions of the 22 swg wire through in order to secure it. Then wind the required number of turns, putting a tight twist in the wire at each tapping point, taking care to scrape off the enamel so that the connecting wire can be soldered into place.

Alternatively, as I did in my first coil, I inserted printed circuit board (PCB) terminal pins into the tube to secure the wire to at the start and finish points of the coil and at each tapping point, as you can see in the photograph below. This involved drilling a hole in the soft plasic of the tube slightly smaller than the PCB pin and forcing the first pin in for a tight fit. The enamel must be scraped of the wire, wrapped arount the pin with a single turn and then soldered in place - quickly to avoid melting the plastc! Then the first turn of the coil is made, another hole drilled and pin inserted and wire scraped clean of enamel and soldered to the pin. Proceed until all the turns and tapping points have been made according to the diagram.

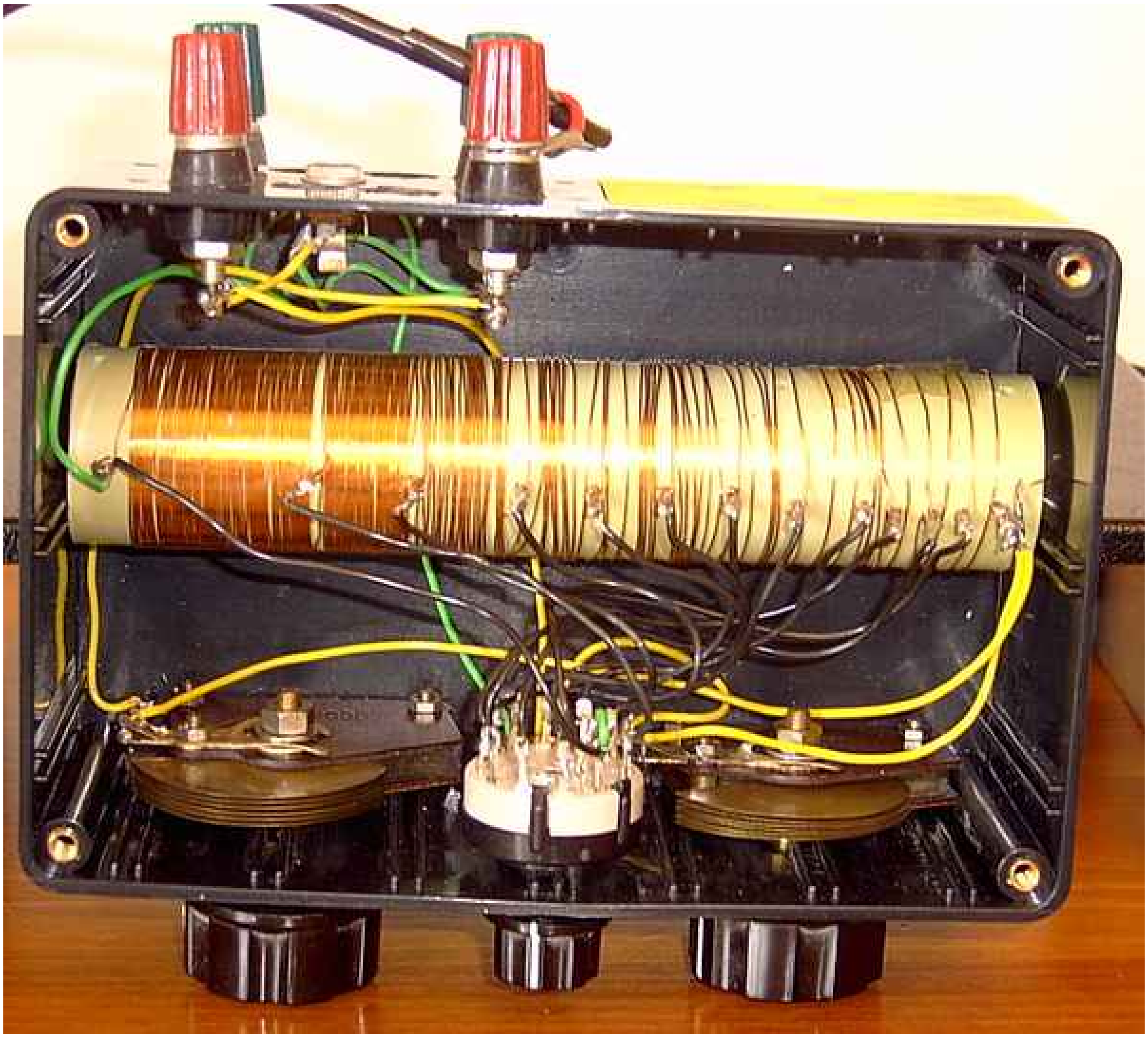
The diagram below shows the number of turns between each tapping point:



Once the coil is complete the tapping points can be wired to the 12 way switch by using short lengths of hook-up wire (e.g. 7/0.2mm pvc covered), being careful to wire the into the circuit exactly as in the diagram.

The Mk1 ATU using the T type circuit

The rear panel of the Mk1 ATU showing the aerial input and output terminal posts.
A 3.5mm jack socket is also included as an alternative output socket for convenient connection to a portable radio via a length of flexible 50 ohm coaxial cable



Internal view of the Mk 1 Antenna Tuning Unit showing the coil and its 12 tapping points, the range switch and two space-saving Jackson type solid dielectric tuning capacitors. The potentiometer that forms the variable attenuator is hidden from view by the range switch.

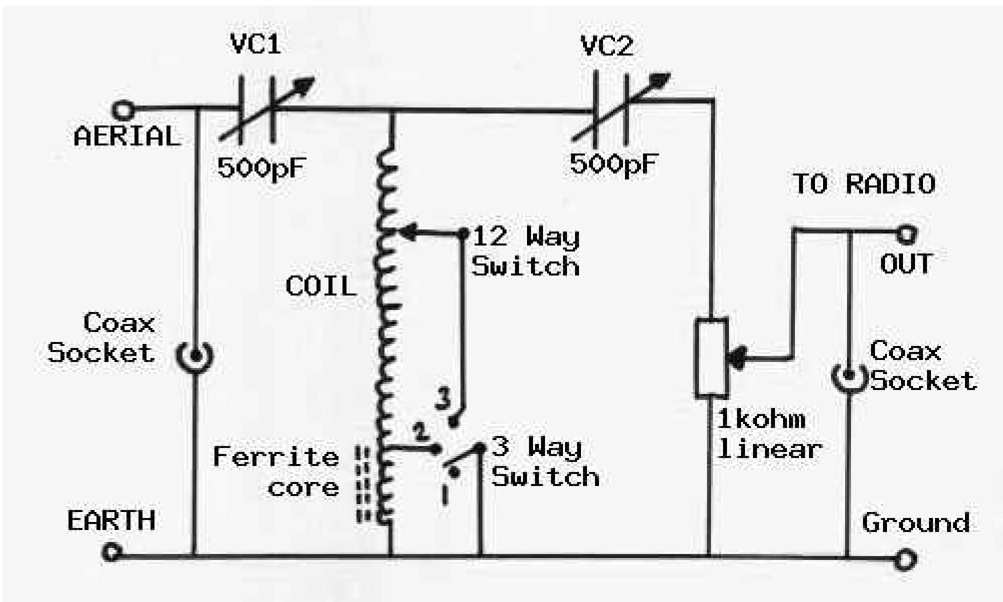
The Mark 2 Aerial Tuning Unit

The Mark 2 Antenna Tuning Unit

The Mark 1 ATU described above was initially made using the Pi match circuit and when I made this, the Mark2, I used the T match circuit design and when I found that it worked even better I modified the Mark 1 to also use the T match circuit layout.

The Mark 1 is used for a portable radio and therefore is more compact, the Mark 2 is used for the HF-150 so can be a bit larger. It is housed in an aluminium case and uses the larger air-spaced tuning capacitors and also has SO239 sockets are fitted for the input and output.

The coil is larger too, using the same former made from the centre of a fax roll but longer at 220mm to accommodate additional windings to enable coverage of long wave frequencies. An additional switch is also included to give plenty of adjustment while including the long wave range.



The circuit diagram showing the coil and the 12 way switch to adjust the Short Wave ranges and the additional 3 way switch to change to Medium Wave and Long Wave coverage*. The attenuator is simply a 1k ohm potentiometer.
* Position 1 is Long Wave; 2 Medium Wave; 3 Short Wave ranges - adjusted with 12 way switch

<u>Tuning Capacitors</u>: In these circuits, as is the general rule of thumb with radio projects, the moving vanes of tuning capacitors - and therefore the spindles/shafts - are connected to the earthy side of the circuit. Ensuring that the moving vanes are connected to the earthy side minimises 'hand capacitance' effects when touching the adjustment knobs. The fixed vanes are therefore connected to the 'hot' (top) side of the circuit.

You will have to determine which terminals on your particular capacitor are connected to the fixed vanes and which are connected to the moving vanes. It should be able to determine this visually from the physical construction of your particular component, but if you are unsure always use the continuity tester function of your multimeter.

With dual gang variable capacitors with smaller values per gang, it may be desirable to connect the two fixed sets of vanes together in parallel to increase maximum capacitance. For many metal framed air-spaced variable capacitors the moving vanes will effectively be connected together via the brass spindle to the main frame of the capacitor body. The fixed vanes and their associated terminals will be isolated from the metal frame by ceramic,

paxolin, or similar, insulators.

PARTS REQUIRED

1	Self wound coil with 13 tapping points
1	Reel of 22 swg enamelled copper wire
1	Reel of 30 swg enamelled copper wire (for longwave part)
1	Coil Former **220mm** long & approx **30mm** diameter
1	12 way switch
1	3 way switch
2	500pF tuning capacitors (200pF or 365pF can also be used)
1	1 k ohm linear potentiometer
2	Red Terminal posts
2	Green terminal posts
2	SO239 sockets
1	Aluminium case 220 x 130 x 65 mm + rubber feet

See additional notes below >

SOURCES FOR TUNING CAPACITORS

Old broken radio sets - but don't smash a nice one up for the sake of a capacitor! Old radio sets, especially the old 'valved' wirelesses are very interesting and often sound superb and could be quite rare.

J BIRKETT RADIO COMPONENTS,. 25 THE STRAIT, LINCOLN, LN2 1JD. telephone (uk) 01522 520767 http://www.zyra.org.uk/birkett.htm

MAINLINE GROUP http://www.mainlinegroup.co.uk/jacksonbrothers/index.htm]

COIL WINDING DETAILS

The coil is essentially the same as the coil described above being wound on the centre of a fax roll or any similar former approximately 30mm in diameter, but slightly longer at 220 mm long. In this case I secured the start and the finish of the windings by simply looping the 22 swg enamelled copper wire through two small holes at each ends of the former to secure it in place. The taps are formed by simply twisting the wire into a loop at each specified interval, to form the connection points to the range switch, making sure that all the enamel is scaped off so that the connecting wires to the switches can be properly soldered in place.

One difference with this coil is that it is designed to cover the Long Wave band too, and the final 110 turns are wound from slightly thinner 30 swg enamelled copper wire, this was done simply to save space. Inside the tube at this end are placed a couple of short lengths of ferrite rod, no longer than 50mm. These are then adjusted, once the ATU is functioning, to give the required tuning range. Alternatively more windings could be added to the final winding to increase its inductance until the desired range is achieved.

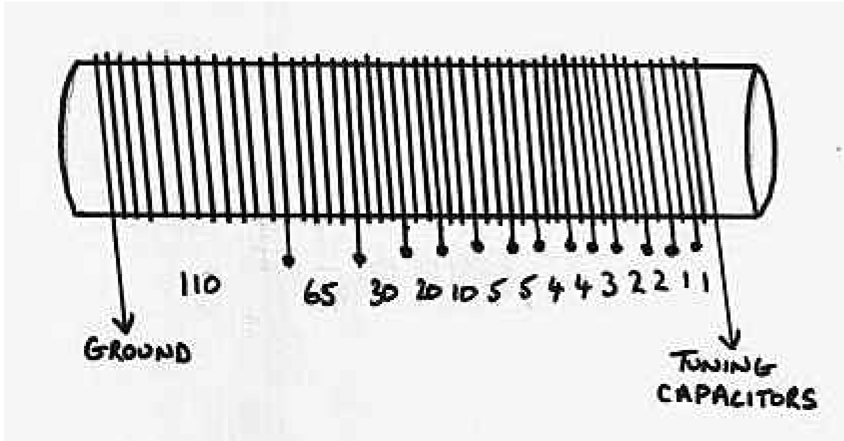
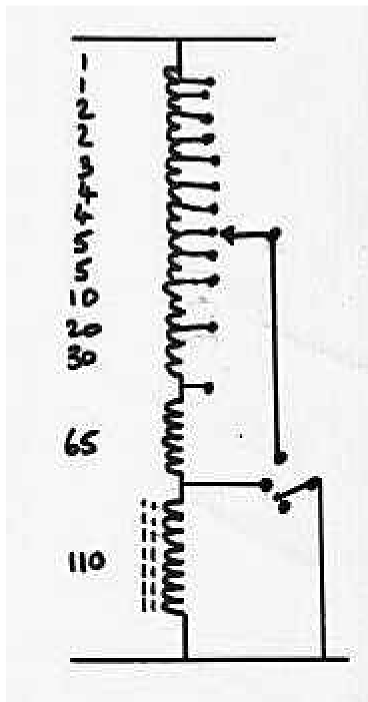


Diagram showing the number of turns between each tapping point



Detail of tapping point intervals and how the coil is wired into the circuit

Detail of tapping point intervals and how the coil is wired into the circuit

The rear panel. On the left the input terminal posts for the aerial and earth wires, with the addition of a SO239 socket for the connection of coaxial cable. On the right the SO239 coaxial output socket for connection to a radio with a coaxial input socket also provided are the alternative terminal posts for single wire output and ground connections to the radio.

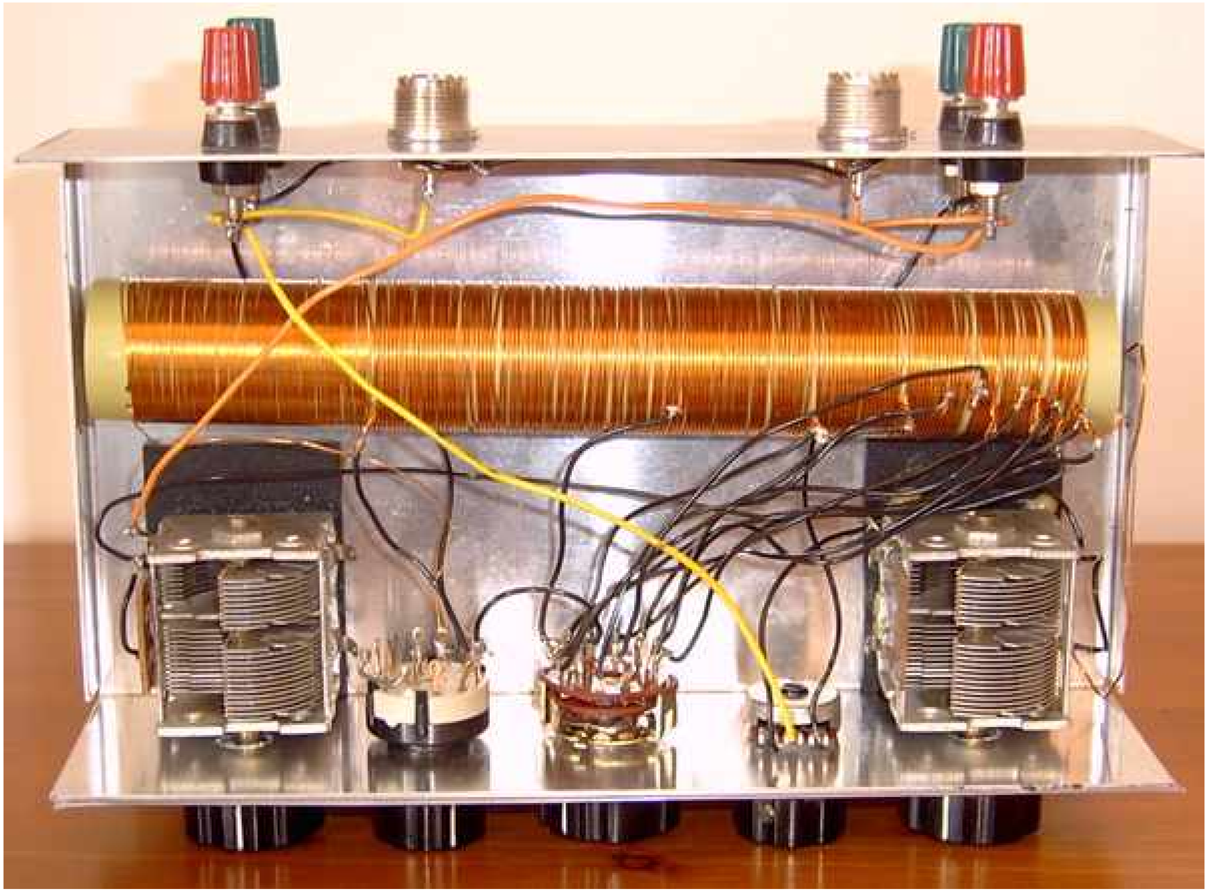


Photo showing the relatively straightforward internal construction of an ATU.
2 large air-spaced tuning capacitors, range switches, potentiometer, and coil with 14 tapping points.

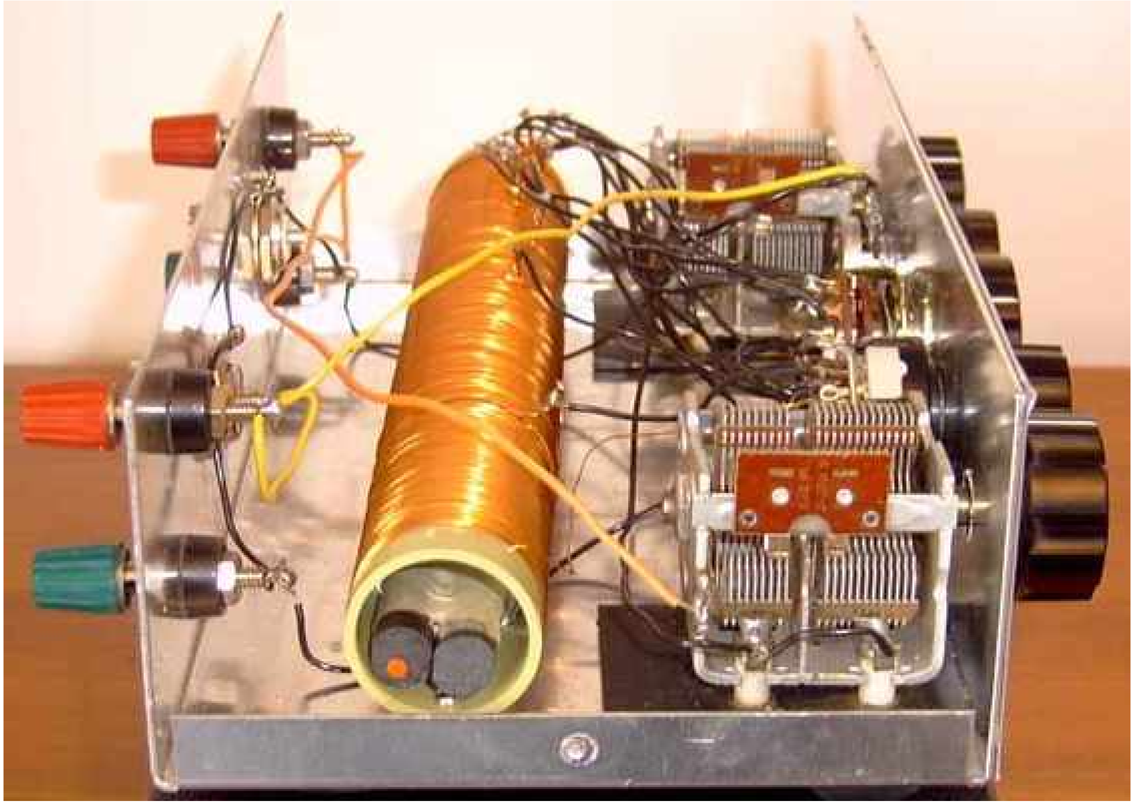


Photo showing how two 2 inch lengths of ferrite rod are put inside the coil at the longwave end of the coil to provide coverage of these low frequencies

ADDITIONAL NOTES:

Thank you to Dr Paul S Crawford who e-mailed us with this additional useful advice:

"You have basically have a capacitor input system connected to the antenna, my own preferance is always to put a 100K Ohm 'bleeder' resistor to GND on such an input just to stop any static build up on hot dry days, etc. Of course, you might also want to include a neon lamp across the input as a crude (but cheap) induced lightening surge arrestor as well.

Regards,
Paul "

Thanks Paul for taking the trouble to get in touch. The lightning arrestor is certainly an excellent safety feature, and if you are troubled with noise caused by a build up of static on the aerial wire, then the 100k resistor is a good tip.

A Question About The Daiwa CL-22 antenna coupler

Dear Sir, I hope you can answer a few questions for me, if you can help me, it will be gratefully appreciated, firstly i am 11 years old, and have just started SWL listening with a DX 394 radio, been using a end fed long wire about 25m long into back of radio.

Recently bought a Daiwa cl-22 coupler(atu) at a car boot sale for £3, it looks in mint condition, but didn't come with any operating instructions, and scoured the internet for some with no effect.
the ATU, has 3 controls on the front..... one marked Receiver, one marked Antenna, both theses are variable controls, and one marked band (A to G), i understand the Band control, also the Antenna control, what is mystifying me, is the variable control marked Receiver ?.

Also on the rear of ATU is 4 screw terminals, grouped in pairs, one marked Receiver, and the other marked Antenna, the Antenna screw terminals are coloured ,one black and one red, and the same for the Receiver terminals, they are very small screw terminals, looks like they only for very thin wire, my question is how do i connect my long wire to the ATU, and to which terminal?

I really hope you can help me with this, as your web site seems to be the only one, on the internet, which seems to want to help anyone like myself, looking forward to hearing your reply.

Thanking you, Ashley Griffiths. May 2012

Hi Ashley, I am not familiar with this particular unit, but most antenna matching units are similar in operation. One pair of terminals on the rear will be used to connect to the antenna and the other pair to the receiver.

Use RG58 coaxial cable to connect between the a.m.u. and receiver. The red to the centre conductor of the RG58 coaxial cable and the other terminal to the outer shield. Some antennas use coaxial cable to feed to the receiver or a.m.u., but in your case you are using a single random wire as an aerial, so simply connect this to the red terminal.

Often connecting the other (ground / GND) terminal to an earth / grounding stake driven in to soft damp soil outside can help reception. Possibly reducing interference or increasing signal strength. It's worth trying, but it does not always help in every case. I don't know without seeing the physical circuit what the actual circuit topography will be. It could be what is known as a "T" match or perhaps a
"Pi" match. Nevertheless the controls on your a.m.u. will perform the same functions and will likely be as described below.

All three controls will tend to interact with each other. The band control is most likely to be a multi-way switch that selects tapping points on an inductor (coil). This sets the general band of operation - usually from around 3MHz at the longer wavelength end of the short wave (H.F.) bands up to around 30MHz at the shortest wavelengths of the short wave (H.F.) band.

'A' will correspond to one end of the HF band (maybe the shortest wave / highest frequency end) and 'G' the other end (maybe the longest wave / lowest frequency end) - or the other way around. You will determine this by experimentation. The other two controls will normally be variable capacitors. One of these will be on the antenna side of the circuit, while the other will be in the output (receiver) side of the matching circuit.

All the controls have to be adjusted to provide the best impedance match between the receiver which always requires a 50 Ohm antenna impedance and the antenna which will present a complex and varying impedance of just several ohms to (perhaps) many hundreds of Ohms dependent on frequency being used.

For example if you want to listen to a radio station in the 31 metre band and your particular random wire antenna presents 50 Ohms to the receiver's antenna input socket then conditions are well matched and you will not need to use the matching unit, indeed it may have little or no effect and may even induces losses that actually weaken reception!

However if on the 31 metre band your random wire antenna presents an impedance (resistance to an alternating current) of several hundred Ohms or more, or a lot less than 50 Ohms then matching will be poor and some of the signal will be lost. This is when the matching unit can help. By adjusting the controls correctly better impedance matching can be achieved so that more of the

signal is ransferred from the random antenna to the radio receiver.

Each band will be different and will need different amounts of matching. You will need to experiment with the controls and determine the best position of all three that produces the highest signal strength. Make a note of their positions for each HF band on a paper chart so that you can easily and quickly set the correct positions in the future as you hop from band to band on the receiver.

I think that's as much as I can tell you without knowing or seeing the actual a.m.u., but these basic principles are the same for any a.m.u. - I hope that helps!

73
Mike
M0MTJ

Hi Mike, Thanks for sharing your expertise and experience!

I am an American living in Mexico and want to use a longwire antenna of about 130 feet for shortwave listening. Am thinking to bring the signal into the house with a 9:1 unun and RG8x coax, then fine tune with your ATU MK II into my Yaesu FT-847.

I don't understand the use of the two ferrite rods.... do they simply enhance the effect of the wiring in the fax tube or do the rods have wires wound around them as well? For the alternative of more windings around the fax tube (I assume that eliminates the need for the rods), about how many more windings?

If I cant find a fax paper tube (30 mm = 1.1811 inches) can I use pvc plumbing pipe that is either 3/4 nominal =1.050 inch outer diameter or 1 inch nominal = 1.315 inch outer diameter?

I cant find 500 pf tuning capacitors so will use 365pf instead...do you know which frequencies I will not be able to tune as a result?

I understand the longwire is directional, pointing toward the far end. Will it likely cover at least 22.5 degrees to each side of its direction?

Is a plastic enclosure just as good as metal, or is shielding an issue? Your photo seems to be of a plastic box, and I can source a plastic enclosure locally.

I wish I could find people like you here where I live in Mexico to share ideas, and passion for whatever hobby it might be, SWL, amateur radio, and so forth.

My great grandparents are British but I haven't visited your country, but will someday. I am envious because you have so many enthusiasts for many interesting activities in your country. I even have the idea that all your countrymen have amazing gardens in their backyards...

When I know what to order so can start to collect the parts...

Thank you Mike, Ransom Peek in Patzcuaro, Michoacan Mexico. (November 2014)

Hi Ransom,

Thanks for your email, it's nice to hear from you.

Using a 'long wire' (I prefer to use the term 'random wire') antenna fed via a 9:1 UnUn is a popular antenna to use at present. It's certainly not the ideal antenna for all circumstances, but as a compromise 'all around' antenna it is probably a pretty good choice.

The two ferrite rods are plain - no additional windings. I simply used them to increase the inductance of that section of the coil windings, therefore allowing use on the lower frequency bands. Their size and position within the tube will dictate the actual frequency range of that section. So - nothing critical, but you may need to experiment a little.

The same applies to the tube. The size is not critical, but it will effect the inductance and hence the frequencies that are covered. Anything (card / paper / PVC) of about 25 to 30 mm (i.e. about 1 inch) will be fine - but again you may need to experiment with the final tapping positions to ensure that your obtain the frequency coverage that you require. I cannot give you absolutes - but the rule is; the larger the diameter of the coil the higher the inductance and hence the lower the frequency - similarly the greater the number of turns on the coil the higher the inductance and hence the lower the frequency - and obviously the converse is true.

365pF cap's are fine and are, in fact, commonly used in ATU's. Naturally the frequency coverage will be a bit different using smaller value cap's, but this can likely be compensated for by adjusting the tapping points if necessary. Lower value cap's may need a few more turns on the coil to compensate.

A straight wire will have some directionality, but depending on the frequency of operation, the pattern will tend to break up into lobes causing some nulls in certain directions. As a rule of thumb, however, the deepest nulls will tend to be off the ends of the wire, while the greatest signal pick up will broadside to the wire.

Please also note that this is a receiving ATU, it has not been rated for transmitting, although it might be ok QRP operation (i.e. < 5watts).

If you have not already done so - just try the 9:1 fed antenna straight into the radio. It may be fine for your swl needs as it is. Then, if you feel that you need a bit of impedance matching, you could try making the ATU. Of course - there can be endless experiments with antennas!

A plastic case should be fine for a receiving ATU.

It is interesting to learn that your great grandparents were from the UK!

As for back gardens here - well they can be of all shapes and sizes, or, indeed, non existent!

Our garden is quite small - but the gardens of many older (1930's) suburban houses could be 100 feet long, or much more. The back gardens of newer houses tend to be very compact - even for larger houses - due to the VERY high cost of land nowadays. Small gardens are called "Postage Stamp" gardens. Of course, many people live in flats and apartments, some of which have shared/communal gardens, and some have no gardens at all. The radio enthusiast therefore has to devise all sorts of compact or 'stealthy' methods of installing an antenna! Maybe a wire aerial supported on a fibreglass fishing pole fixed to the balcony, perhaps.

I hope that helps! Good luck with your projects.

73
Mike
M0MTJ

More about Components / Aerials / UnUns and Baluns

Simplification: If do not need cover the long wave or medium wave bands then you can omit those windings. This will make construction and wiring simpler.

Variable Capacitors: The variable capacitors can be anything over 200pF in value - just bear in mind that smaller values will not give as much adjustment range as larger values. Using a smaller value capacitor, such as 200pF, should not be a problem but it may require some experimentation with different tapping spacings, or perhaps using a greater number of tapping points, to obtain the required band coverage.

The use the miniature polyvaricon cap's which have a value of around 200pF will help keep costs low and will work perfectly well in receiving ATU's. You might also find these in old junk pocket transistor radios that can be salvaged for these sorts of projects.

Aerials and Feeder arrangements:

This will be a case of experimentation to find what provides the best reception - whether that be best signal strengths from stations of most interest, or lowest noise - i.e. best Signal to Noise ratio (S/N).

Try a 'long wire' aerial to begin with. Actually the expression 'Random Wire' is a more accurate and better terminology. Connect the aerial wire directly to the ATU. This may give good signal strengths but may also be noisy.

If you are troubled with noise:

Try connecting coaxial antenna cable to the ATU with shield to the ground terminal and centre conductor to input terminal. Take the coax to the outside the house and connect the the inner conductor to the random ('long') wire aerial. This may lower noise - or may just lower signal strength! It is important to attempt to judge whether the Signal to Noise ratio has improved. It might be found that actual strengths have been lowered, but that the noise level may have reduced by a greater extent, so as long as the signals are still resovable the overall noise should be lower.

Further experiments: Experiment with connecting the far end of the coax inner conductor to the random aerial wire but also connect the shield of the coax to an earth stake in the back yard or garden. This will change the aerial system - possibly reducing local noise pick up - possibly not!

Also experiment with a matching transformer at the far end of the coax. The use of an UNbalanced to UNbalanced transformer would be the most appropriate for this purpose - so try winding a simple 4:1 ratio UNUN or perhaps try a 9:1 UNUN which may work even better.

There are numerous UNUN designs on the web often using a toroid core, while some designs also use a 10mm ferrite rod. The wire used to make the windings might be enamelled copper wire or even p.v.c. covered wire. Either method would be good for these experiments. Here are some links for constructing UnUns and BalUns:

UnUn designs

M0UKD - 9:1 Unun (so-called magnetic longwire balun):
http://www.m0ukd.com/Magnetic_Long_Wire_UnUn/index.php

How To Build an UNUN by G7LRR:
http://www.pcsystems-ss.co.uk/g7lrrweb/index.php?module=pagemaster&PAGE_user_op=view_page&PAGE_id=52&MMN_position=77:37

IW7EHC - Unun Design for Longwire antennas:
http://iw7ehc.altervista.org/ununEN.htm

Balun designs

Build An Air Wound 1:1 Choke Balun For HF: http://www.hamuniverse.com/balun.html

1:1 Balun for balanced dipole aerials : http://www.m0ukd.com/1to1_HF_Balun_for_dipole/index.php
http://warga11mc.blogspot.com/2010/07/balun-11-14.html

Cost Effective 1:1 Current Mode Balun:
http://www.arising.com.au/people/Holland/Ralph/cmbalun.htm

Inexpensive 1:1 Balun: http://oz1jux.dk/balun.htm

Build a 1:1 Coaxial Balun: http://www.iw5edi.com/ham-radio/?a-1-1-coaxial-balun,41

Broadband Balun Design: http://www.qsl.net/ta1dx/amator/broadband_baluns.htm

Step-By-Step Construction of a 4:1 Current-Type (Guanella) Balun:
www.n0ss.net/qrp_4-1_guanella-type_balun.pdf

Making Baluns 1:1 and 4:1 Baluns - Swindon and District Amateur Radio Club:
http://www.sdarc.net/wp-content/uploads/pdfs/Making_Baluns.pdf

Air Wound 4:1 balun: http://www.combotec.com/projects/balun14/balun14.html

Home brew a 4:1 balun: http://www.rason.org/Projects/balun/balun.htm

4:1 balun for 160 to 10 meters by Clay Wynn: http://www.hard-core-dx.com/nordicdx/antenna/feed/4_1balun.html

4:1 and 1:1 Balun ideas by PD7BZ
http://www.pd7bz.com/radioprogs/manuals/balun_transformer.htm

Balun Winding: http://users.catchnet.com.au/~rjandusimports/balun_winding.html

4:1 and 1:1 Balun construction by M0SCG: http://www.m0scg.org.uk/Projects/?p=207

QRP 4:1 Balun for 160 to 10m : http://www.dxzone.com/cgi-bin/dir/jump2.cgi?ID=16753

UK Source for Silver Plated PTFE (Teflon) covered wire for winding higher power baluns:
http://wires.co.uk/acatalog/ptfe_covered.html
14awg / 16 swg or 0.16 mm dia wire. 12awg / 14swg 0.2mm dia wire and larger toroid for higher

powers.

Balun using T200-2 toroid (17 turns of e.c.w.) or T200A-2 toroid (13 turns of e.c.w.) for 400 watt H.F. Balun.
T400-2 Toroid (14 turns of e.c.w.) for 1000 watt H.F. Balun.
Amidon ferrite & powdered iron cores & ferrites: https://www.amidoncorp.com
Bytemark ferrite & powedered iron cores & ferrites: http://www.cwsbytemark.com
http://www.bytemark.com

I hope you enjoy building one of these useful devices, and enjoy even more the benefits that an ATU can bring to your listening post with minimal expense.

73
Mike
MØMTJ

Radio Stations & Memorabilia | **Loop & Frame Aerials** | **Copper Tube Antenna**

DXing & Short Wave | **Make A Signal Meter** | **Riding On A Radio Wave**

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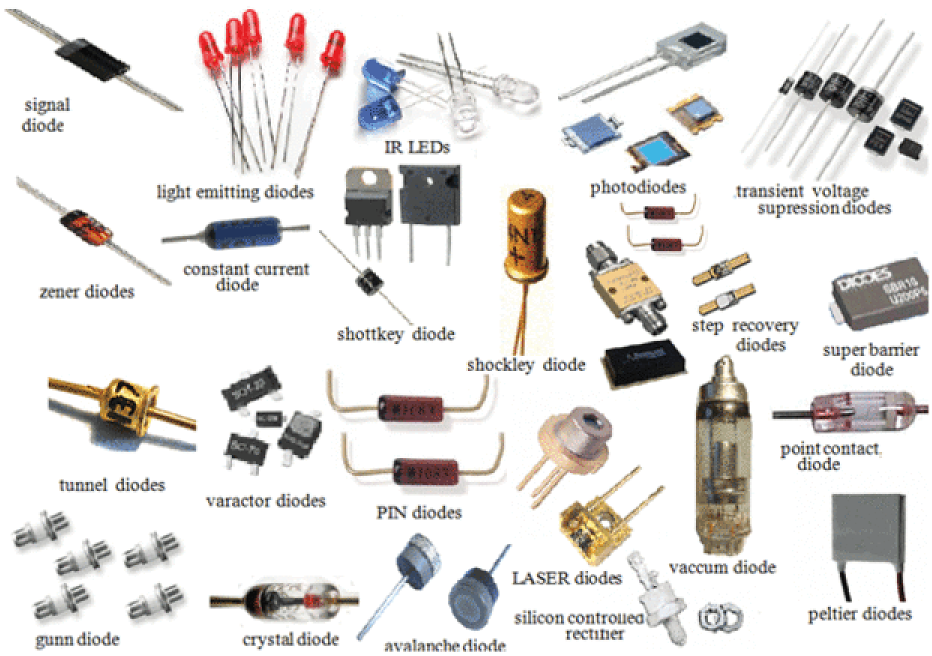

Types of Diode
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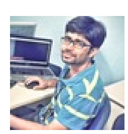
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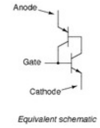

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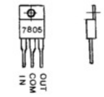

(/id/78xx-Regulators-Ics/)

Types of Diodes

by dhruvil_patel (/member/dhruvil_patel/) in electronics (/technology/electronics/)

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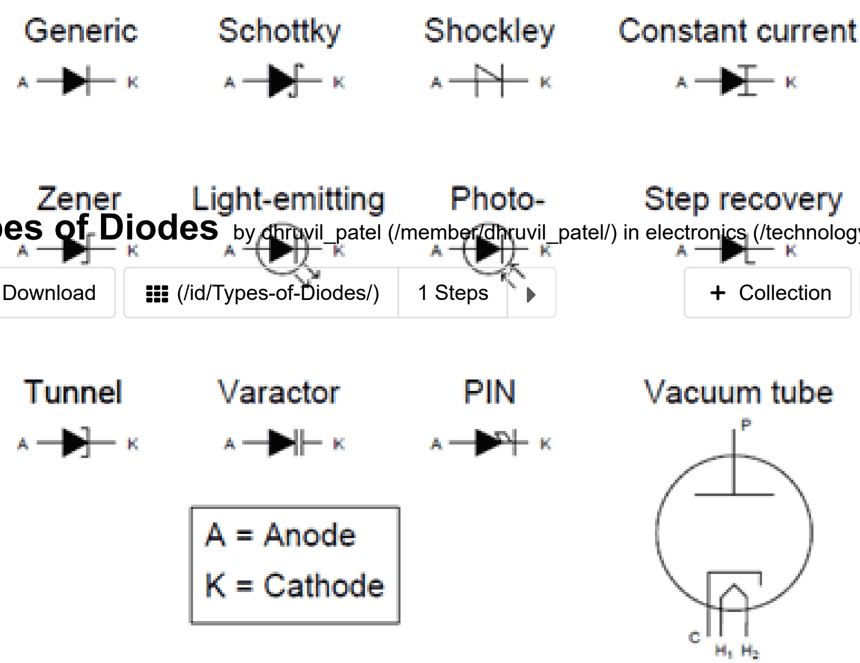


Various symbols of Diode

(https://cdn.instructables.com/FFO/YA9J/H5R9FCF5/FFOYA9JH5R9FCF5.MEDIUM.gif)

A diode is a two-terminal device, having two active electrodes, between which it allows the transfer of current in one direction only. Diodes are known for their unidirectional current property, wherein, the electric current is allowed to flow in one direction. Basically, diodes are used for the purpose of rectifying waveforms, and can be used within power supplies or within radio detectors. They can also be used in circuits where 'one way' effect of diode is required. Most diodes are made from semiconductors such as silicon, however, germanium is also used sometimes. Diodes transmit electric currents in one direction, however, the manner in which they do so can vary. Several types of diodes are available for use in electronics design. Some of the different types are:

Light Emitting Diode (LED): It is one of the most popular type of diodes and when this diode permits the transfer of electric current between the electrodes, light is produced. In most of the diodes, the light (infrared) cannot be seen as they are at frequencies that do not permit visibility. When the diode is switched on or forward biased, the electrons recombine with the holes and release energy in the form of light (electroluminescence). The color of light depends on the energy gap of the semiconductor.

Avalanche Diode: This type of diode operates in the reverse bias, and used avalanche effect for its operation. The avalanche breakdown takes place across the entire PN junction, when the voltage drop is constant and is independent of current. Generally, the avalanche diode is used for photo-detection, wherein high levels of sensitivity can be obtained by the avalanche process.

Laser Diode: This type of diode is different from the LED type, as it produces coherent light. These diodes find their application in DVD and CD drives, laser pointers, etc. Laser diodes are more expensive than LEDs. However, they are cheaper than other forms of laser generators. Moreover, these laser diodes have limited life.

Schottky Diodes: These diodes feature lower forward voltage drop as compared to the ordinary silicon PN junction diodes. The voltage drop may be somewhere between 0.15 and 0.4 volts at low currents, as compared to the 0.6 volts for a silicon diode. In order to achieve this performance, these diodes are

constructed differently from normal diodes, with metal to semiconductor contact. Schottky diodes are used in RF applications, rectifier applications and clamping diodes.

Zener diode: This type of diode provides a stable reference voltage, thus is a very useful type and is used in vast quantities. The diode runs in reverse bias, and breaks down on the arrival of a certain voltage. A stable voltage is produced, if the current through the resistor is limited. In power supplies, these diodes are widely used to provide a reference voltage.

Photodiode: Photodiodes are used to detect light and feature wide, transparent junctions. Generally, these diodes operate in reverse bias, wherein even small amounts of current flow, resulting from the light, can be detected with ease. Photodiodes can also be used to generate electricity, used as solar cells and even in photometry.

Varicap Diode or Varactor Diode: This type of diode feature a reverse bias placed upon it, which varies the width of the depletion layer as per the voltage placed across the diode. This diode acts as a capacitor and capacitor plates are formed by the extent of conduction regions and the depletion region as the insulating dielectric. By altering the bias on the diode, the width of the depletion region changes, thereby varying the capacitance.

Rectifier Diode: These diodes are used to rectify alternating power inputs in power supplies. They can rectify current levels that range from an amp upwards. If low voltage drops are required, then Schottky diodes can be used, however, generally these diodes are PN junction diodes.

Small signal or Small current diode - These diodes assumes that the operating point is not affected because the signal is small

· **Large signal diodes** - The operating point in these diodes get affected as the signal is large.

Transient voltage supression diodes - This diode is used to protect the electronics that are sensitive against voltage spikes.

· **Gold doped diodes** - These diodes use gold as the dopant and can operate at signal frequencies even if the forward voltage drop increases.

· **Super barrier diodes** - These are also called as the rectifier diodes. This diodes have the property of low reverse leakage current as that of normal p-n junction diode and low forward voltage drop as that of Schottky diode with surge handling ability.

· **Point contact diodes** - The construction of this diode is simpler and are used in analog applications and as a detector in radio receivers. This diode is built of n – type semiconductor and few conducting metals placed to be in contact with the semiconductor. Some metals move from towards the semiconductor to form small region of p- tpye semiconductor near the contact.

· **Peltier diodes** - This diode is used as heat engine and sensor for thermoelectric cooling.

· **Gunn diode** - This diode is made of materials like GaAs or InP that exhibit a negative differential resistance region.

· **Crystal diode** - These are a type of point contact diodes which are also called as Cat’s whisker diode. This didoe comprises of a thin sharpened metal wire which is pressed against the semiconducting crystal. The metal wire is the anode and the semconducting crystal is the cathode. These diodes are obsolete.

· **Avalanche diode -** This diode conducts in reverse bias condition where the reverse bias volage applied across the p-n junction creates a wave of ionization leading to the flow of large current. These didoes are designed to breakdown at specific reverse voltage in order to avoid any damage.

· **Silicon controlled rectifier -** As the name implies this diode can be controlled or triggered to the ON condition due to the application of small voltage. They belong to the family of Tyristors and is used in various fields of DC motor control, generator field regulation, lighting system control and variable frequency drive . This is three terminal device with anode, cathode and third controled lead or gate.

· **Vaccum diodes** - This diode is two electrode vacuum tube which can tolerate high inverse voltages.

Diodes are used widely in the electronics industry, right from electronics design to production, to repair. Besides the above mentioned types of diodes, the other diodes are PIN diode, point contact diode, signal diode, step recovery diode, tunnel diode and gold doped diodes. The type of diode to transfer electric current depends on the type and amount of transmission, as well as on specific applications.

--please vote for me-----------------

Source :- https://en.wikipedia.org

thanx....

Step 1:

Comments

We have a be nice comment policy.
Please be positive and constructive.

I Made it! Add Images Post Comment

madd71 (/member/madd71/) 2018-01-10 Reply

Hi, i'm quite new to electronics. Do some diodes have a little spark/light flashing when it's broken

sundustalpur (/member/sundustalpur/) 2016-12-31 Reply

marvelloussss.....

HareeshK1 (/member/HareeshK1/) 2016-04-04 Reply

fine

mohitk39 (/member/mohitk39/) 2016-02-05 Reply

Can u please tell me which diode used in electromagnetic stickers. Which is the smallest led diode used in that sticker

Muhammadr89 (/member/Muhammadr89/) 2016-01-16 Reply

i really impressed your notes thanks admin

shaaz24 (/member/shaaz24/) 2015-10-16 Reply

Please tell me about this diode.

(https://cdn.instructables.com/F2G/TQAF/IFSLOUD5/F2GTQAFIFSLOUD5.LARGE.jpg)

NollyC (/member/NollyC/) 2015-09-16 Reply

MichaelP59 (/member/MichaelP59/) 2015-08-22 Reply

If you need more information about Tunnel Diode just visit this site: http://911electronic.com/ It is site about electronics parts, symbols, characteristics and all basics.

azumi olu (/member/azumi+olu/) 2015-06-01 Reply

Easy to understand.....great job

Elis123 (/member/Elis123/) 2015-04-16 Reply

rajugopalb (/member/rajugopalb/) 2015-04-12 Reply

This is the basic concepts of DIODES..I gathered very imp information....,,Gud stuff

sanjay.baidya.50 (/member/sanjay.baidya.50/) 2015-04-07 Reply

thanks............very useful for small innovation.

lovekush.choudhary.96 (/member/lovekush.choudhary.96/) 2015-01-15 Reply

i want to convert 12v ac to dc which diode use this diagram

M.shahbazQ (/member/M.shahbazQ/) ▸ lovekush.choudhary.96 (/member/lovekush.choudhary.96/) 2015-02-19 Reply

just simple in4007 silicon diods for mas 5 amp or simpe buy a redy made brdge that wich only 10 rupee.

M.shahbazQ (/member/M.shahbazQ/) 2015-02-19 Reply

its help full lkn just symbols.not detail these PN junction break voltage and power etc..............

brijesh.sinha2 (/member/brijesh.sinha2/) 2014-11-07 Reply

thnx.... its very useful...

Muhammad Tanvir (/member/Muhammad+Tanvir/) 2014-10-29 Reply

Its very helpful, thanks...

awesomelumens (/member/awesomelumens/) 2014-09-23 Reply

very helpful thanks

pavitra.pavi.182 (/member/pavitra.pavi.182/) 2014-09-05 Reply

Thanks for gaving this..!!
This very usefull for me..!!

florlayamp (/member/florlayamp/) 2014-06-18 Reply

great information. ill be able to use this for sure!

Ian01 (/member/Ian01/) 2014-01-08 Reply

That constant current diode symbol is new to me. The one I've seen looks like ---O|---.

phonewill40 (/member/phonewill40/) 2013-11-05 Reply

Good very Good Stuff...

sylvain01 (/member/sylvain01/) 2013-03-08 Reply

thank you very convenient for me

rimar2000 (/member/rimar2000/) 2012-08-12 Reply

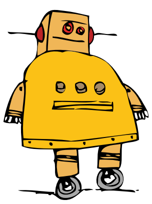
Thanks for this useful info.

bluesnblue (/member/bluesnblue/) ▸ rimar2000 (/member/rimar2000/) Reply

2012-12-12

Good Info...

More Comments



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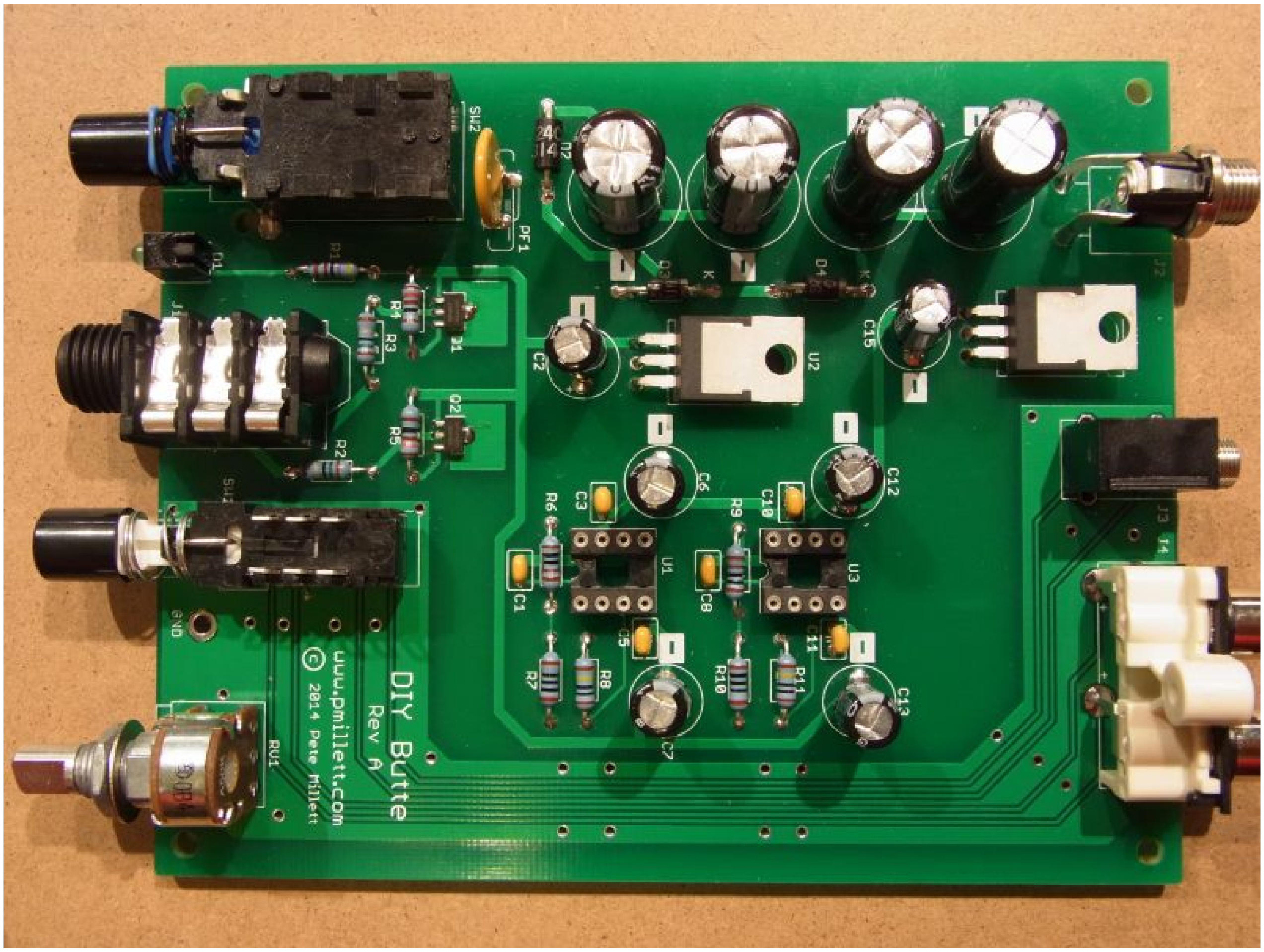
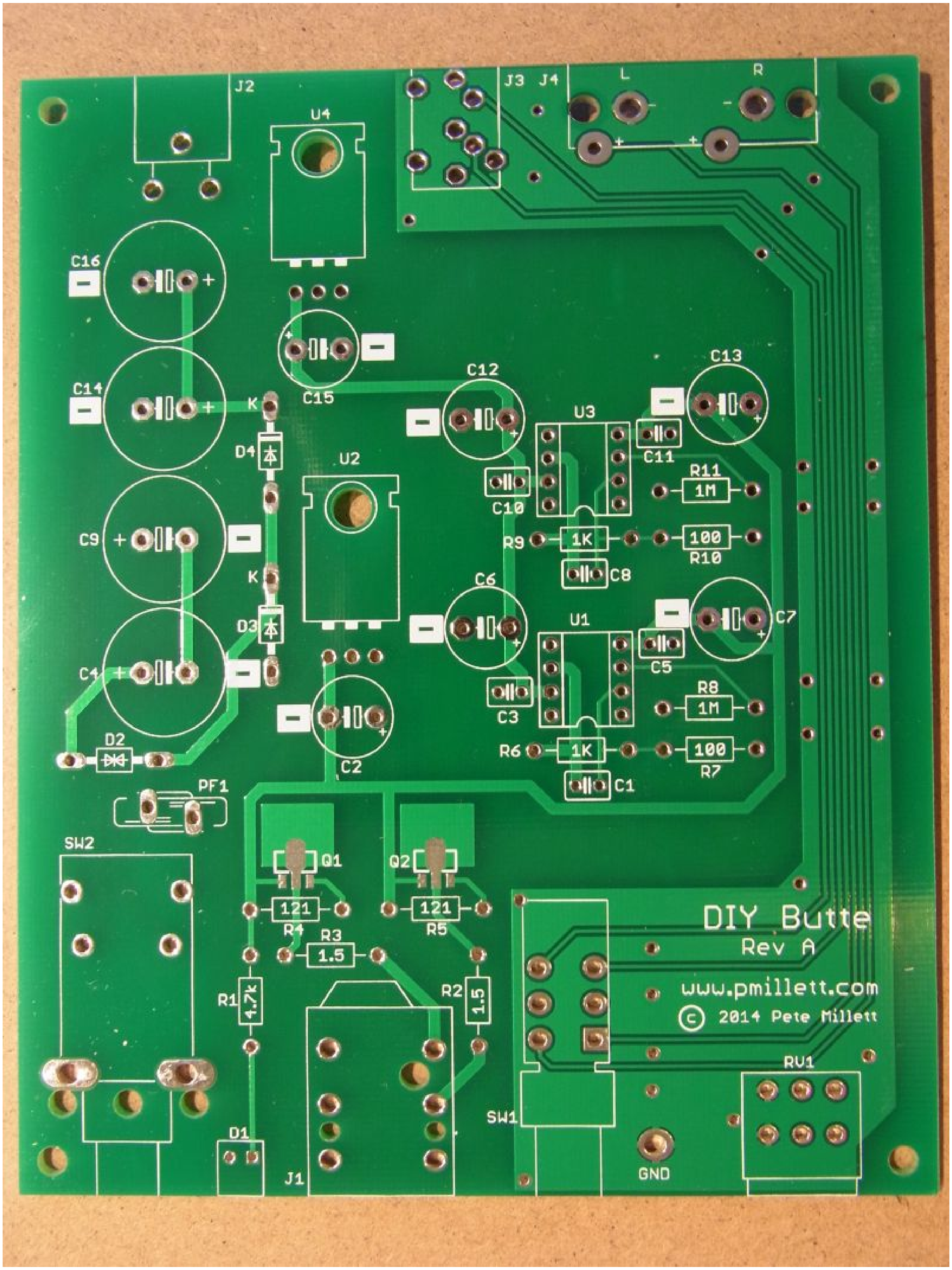
Sitemap (/sitemap/)

[DIY Audio Home](http://www.pmillett.com)

The "Butte" DIY solid-state headphone amp


DIY Butte
Rev A
www.pmillett.com
© 2014 Pete Millett

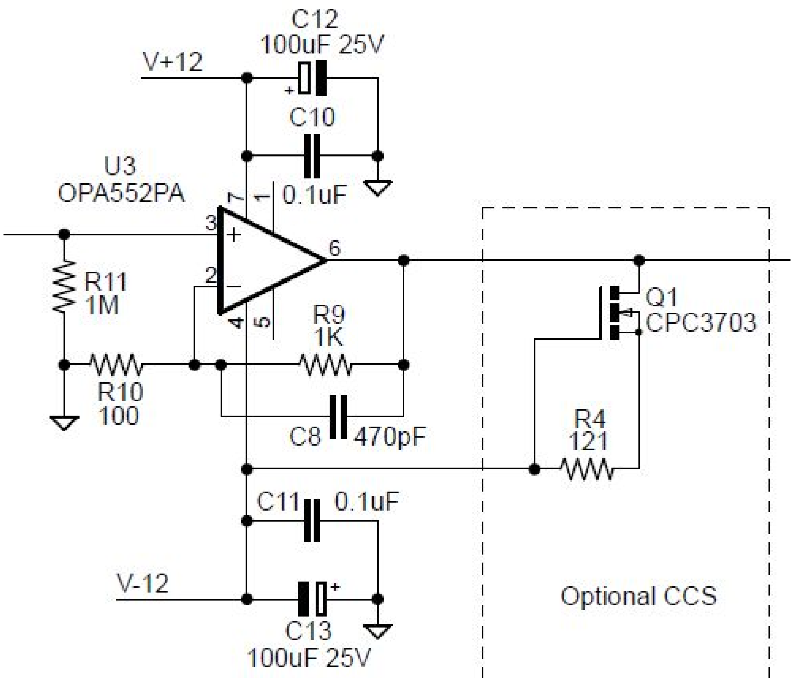


This is a DIY version of a solid-state headphone amp that was sold commercially for a little while. It's basically the same circuit as the Apex Butte, but has been changed to a through-hole assembly, and a few parts changed to make it less expensive to build.

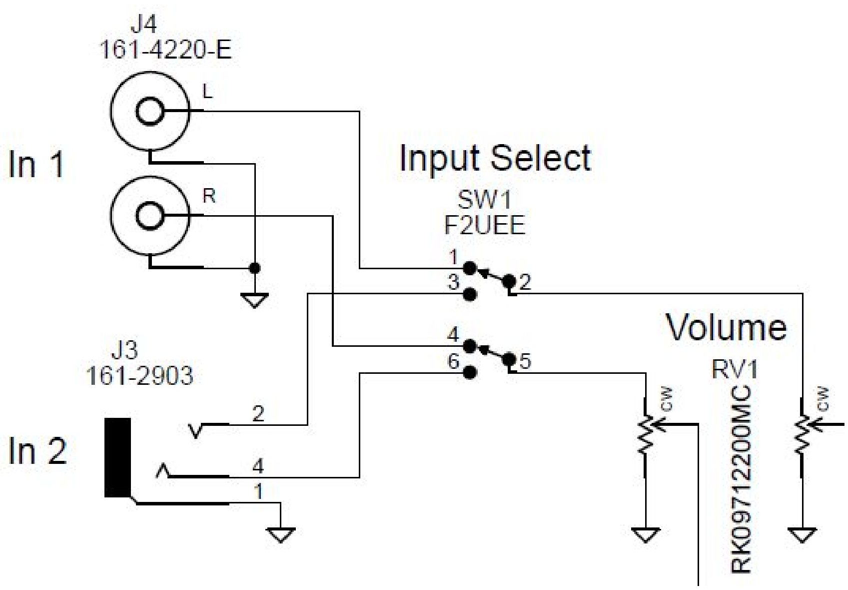
It's an excellent first-time project. The detailed assembly manual gives step-by-step directions - I recommend that you download it and have a look. The total cost (as of 2/2015) is $76 not including an enclosure. You can buy a matching enclosure on eBay (shown in the photos above), or make your own.

All components are mounted on a single PCB, which is available from the pmillett.com eBay store. All parts (including the power supply and knob, but not the PCB or enclosure) are easily sourced from one place, Mouser Electronics. To buy the parts, all you have to do is load the Mouser BOM, and hit "Order Project". More detailed instructions are available in the assembly manual.

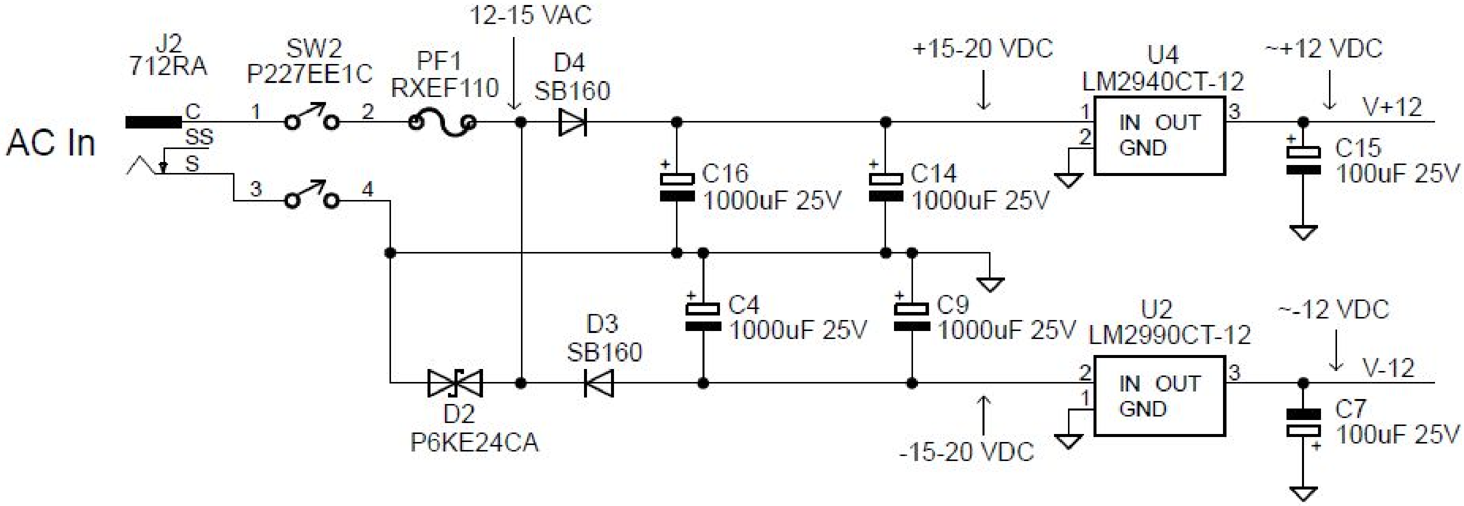
The amp circuit is straightforward, using a single power opamp. The OPA552 is a very good choice for this use - it has exceptionally low distortion and good drive capability. An optional CCS circuit can be used to draw current from the opamp output to the negative supply, essentially biasing it into class A for very small signals.



It has two inputs on the rear panel, one RCA, one 1/8" mini stereo phone jack.



The power supply is designed to be simple and affordable. It uses an AC wall transformer, and a voltage-doubler rectifier to generate about +/-18V from a 12V transformer. Linear regulators are used to provide +/-12V to run the amp.



Here are some supporting files:

- Assembly Manual
- Schematic
- Bill of Materials (parts list) PDF file, XLS spreadsheet
- Mechanical drawings of PCB and front and rear panels (zipped DXF files)

The PCB and matching (optional) enclosure are available on eBay.

DIY Audio Home

The "Unnecessarily Complex 300B Amp"

Having never built a single-ended 300B amp, I figured the right thing to do would be to go overboard. So I designed and built this:

There is an article in audioXpress magazine (May, 2009) I put together on this, so I won't post all the details about the design and construction - please buy the magazine! But I will post detailed photos and schematic here that are more readable than those in the magazine.

Here is the schematic (39kB PDF file)

I started with a single-stage driver using a triode-connected EL802 (you could also use the plentiful PL802 but would need a separate filament transformer). The EL802 design performs a little better than the one above (a 2-stage driver using 7044/7119/5687), but suffers from lower gain and high input (miller) capacitance, so it is problematic to use with a passive volume control. But if you intend to drive this with a preamp that has an output impedance of less than about 10kohms, and some gain, this might be a better choice. Here is the schematic (17kB PDF file).

Also, a schematic of a more conventional power supply (19kB PDF file). Note I have not built or tested this!

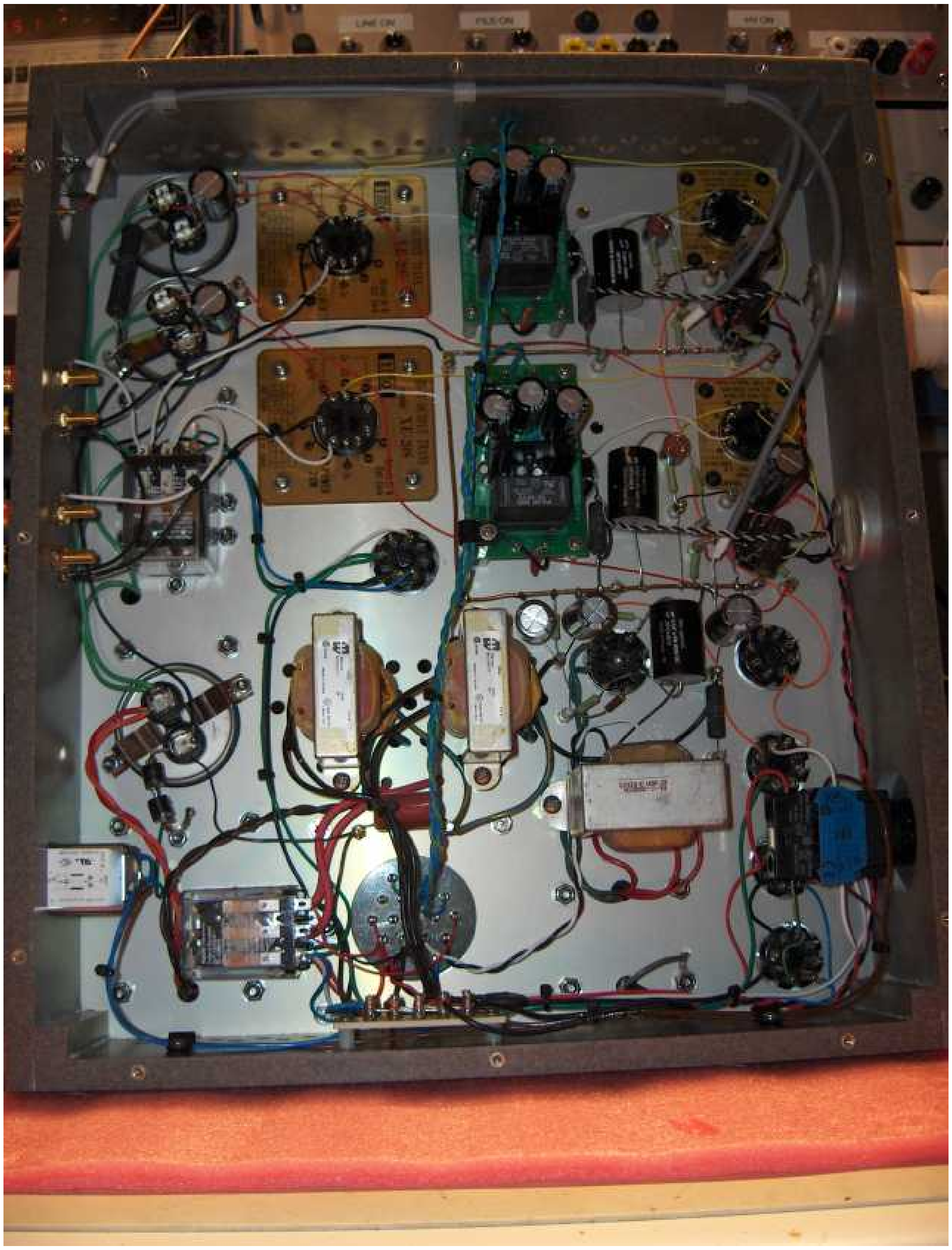
Mechanics: I'll post source CAD files as well as some PDF files for this as I built it. If you have access to CAD tools or want to use Front Panel Express to make the top plate, even if you plan on using some different parts (like transformers), this will give you a big head start.

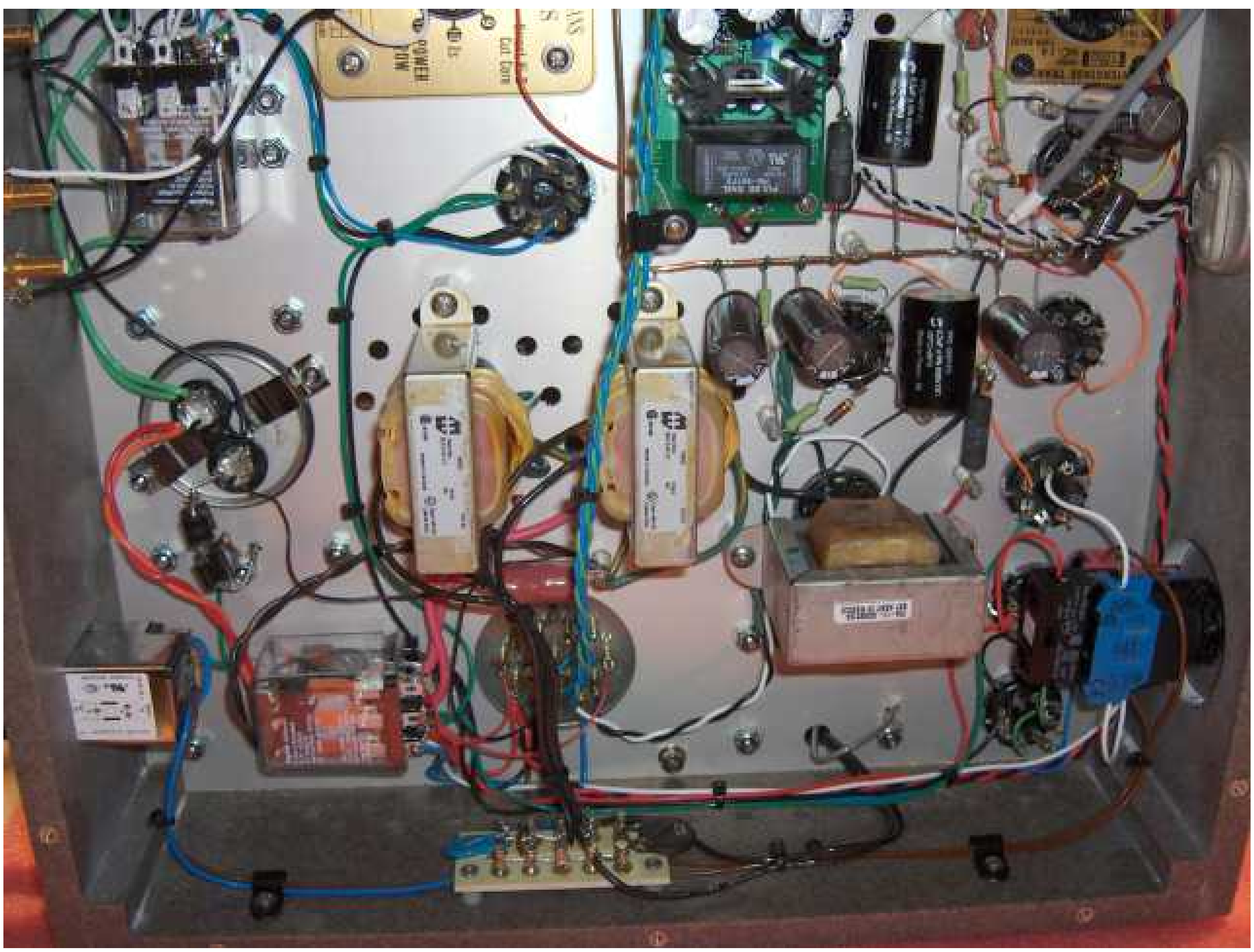
Here's a PDF plot of the AutoCAD layout, viewed from the top (154kB PDF file) or viewed from the bottom (144kB PDF file).

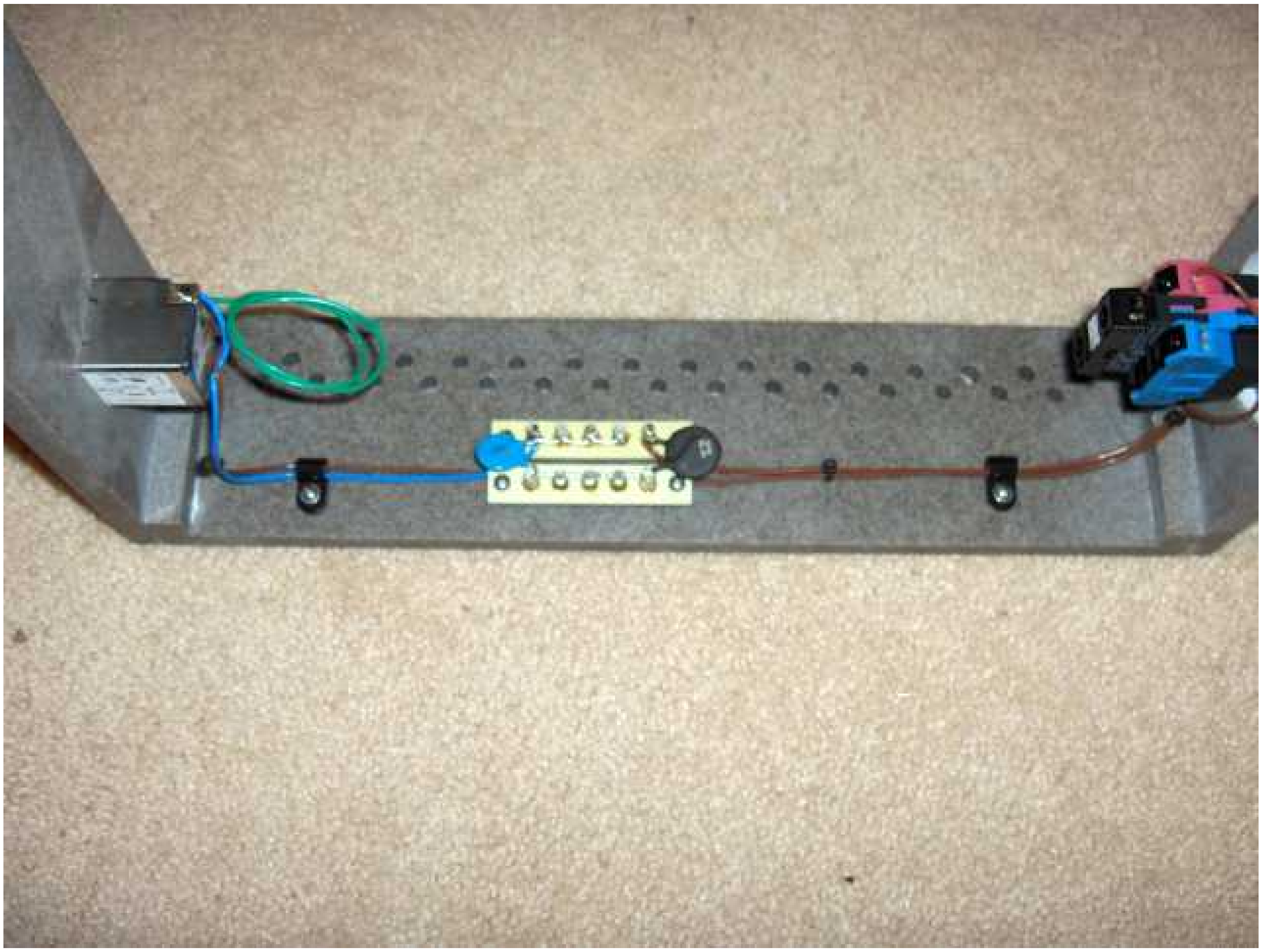
If you have AutoCAD or a compatible CAD program, you can download my mechanical drawing in .DXF and .DWG format (406kB ZIP file)

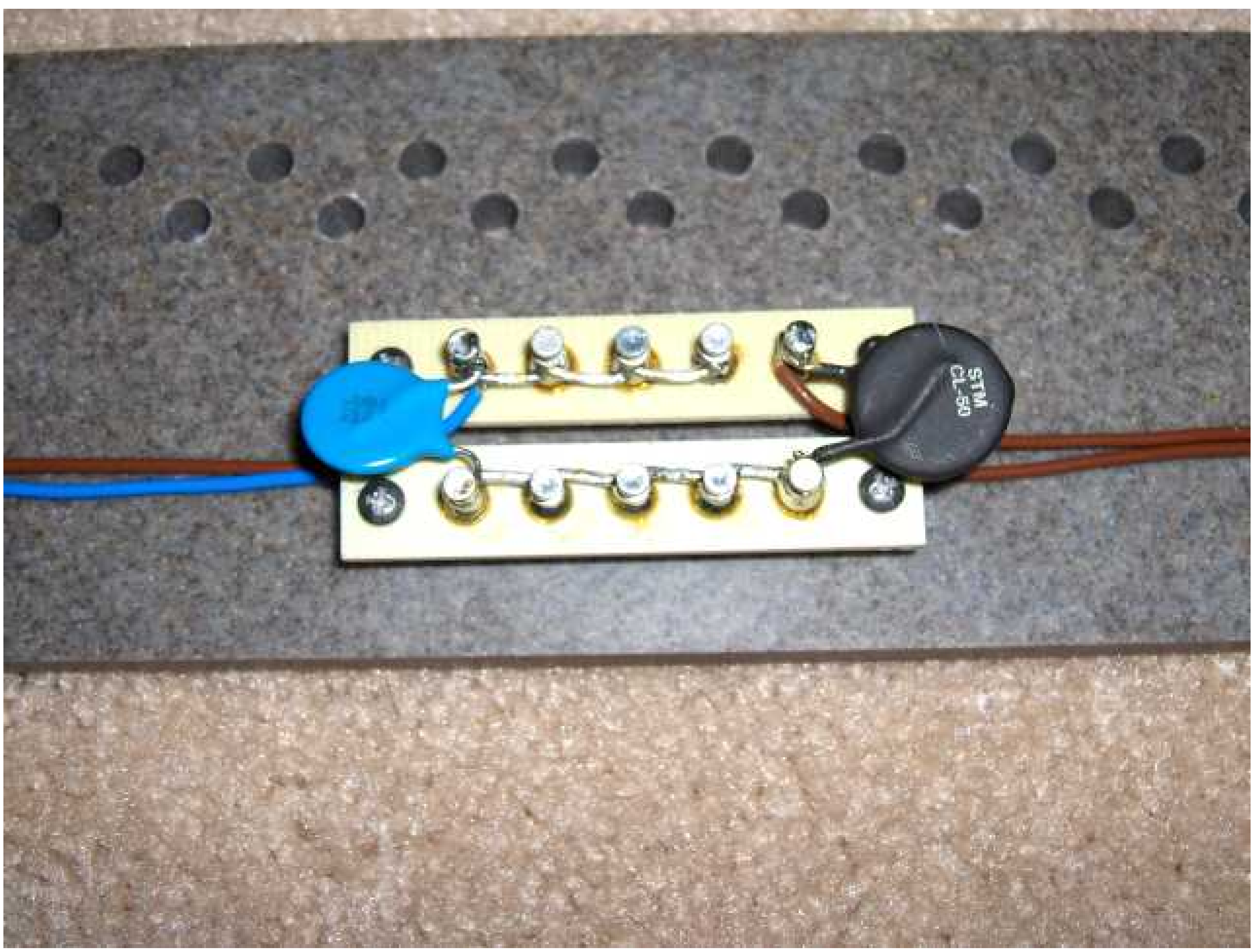
If you want to use Front Panel Express, here is a ZIP archive with my FPE files (2kB ZIP file)

Pictures: Below are photos of the amp as built. The 640x480 thumbnails are linked to full-size images that you can zoom into for better detail...

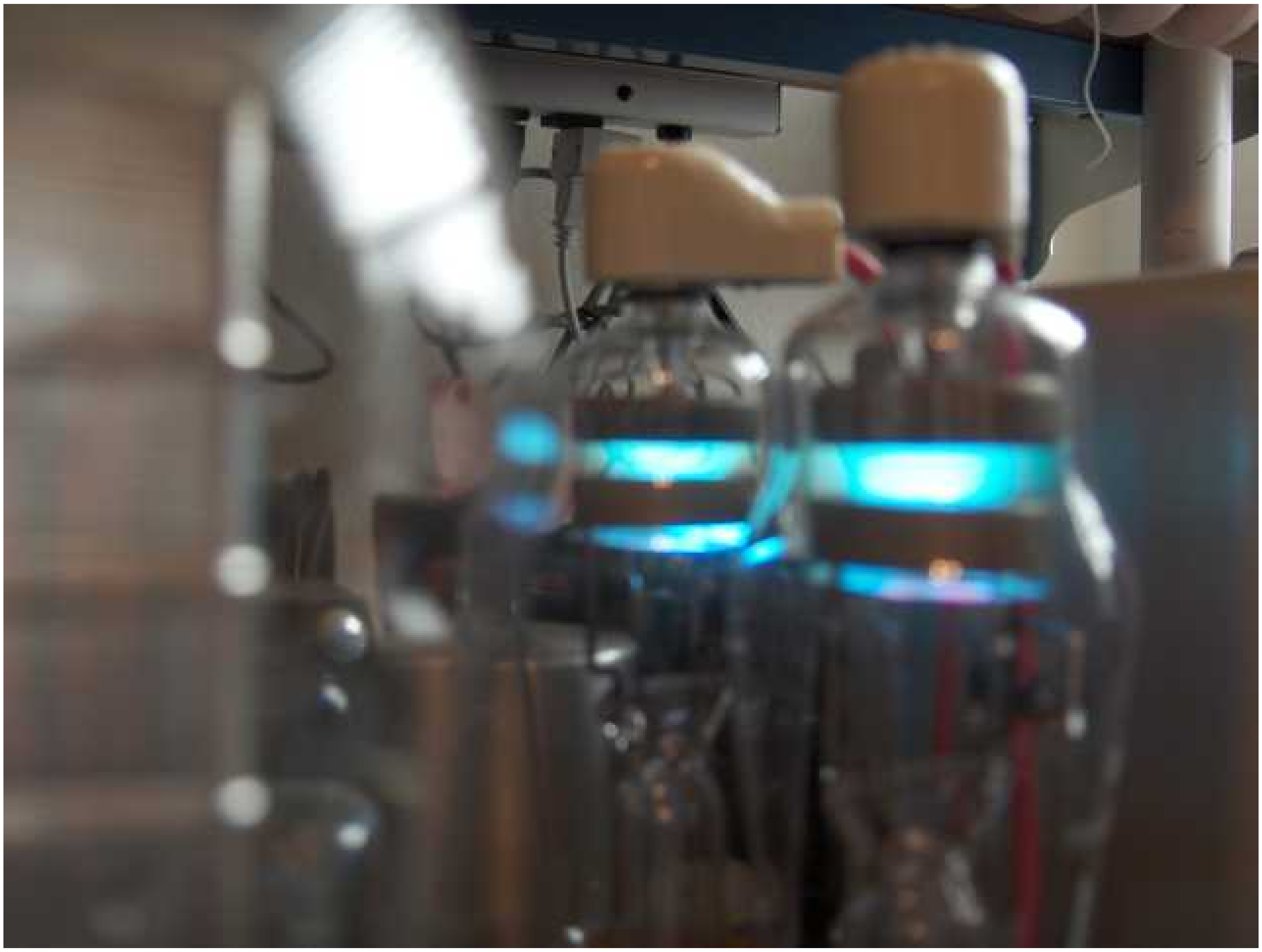







STM
CL-50

And just because it looks cool...



The KJ4IIF Multiband "FAN" Dipole for 160, 80 and 40 Meters

(Optional 20 Meter band addition also)

(Using Techniques and modified formulas from SRI research with Fan Dipoles)

(Refer to the Multiband Fan Dipole project here)

I did not model this with any antenna modeling software. I did it the old fashioned way. With formula's, cut and prune, a cooler full of cold drinks and some friends to help pull that heavy antenna up in the air.
Included at the bottom of this article is a frequency vs, "X" and "R" plus swr results chart for all amateur bands, 2 meters through 160 meters. There is also a link to a harmonic relationship for all bands courtesy of and compiled by N5JNX.
All measurements are taken with an MFJ 259B analyzer.
Apex of the multi band dipole is at 58 feet, Ends of the 160 leg are at 20 feet above ground.
The multi dipole has a 1:1 current Balun at the feed point.

The 160/80/40 meter multiband fan dipole (lower right) mounted on the tower!

CONSTRUCTION DETAILS:

In the photo above, the 160 meter section is on top, 80 meters in middle and 40 on bottom.
On each half of the antenna, all dipoles halfs are connected together at a common point on each side of the center insulator. Then each half is connected to the 1:1 balun at bottom.

In the photo above, the legs of the multi band dipole are spaced 6 inches apart vertically, four inches apart horizontally at the feed point. I used 14 inches of non conductive Lucite six inches wide as shown.
I spaced the dipole legs with 1/2 inch PVC, Six inches from the fed point where the legs come off the Lucite. I drilled 1/4 inch holes through the pvc and threaded the wire through the holes. This keeps the wires separated at the feed point. See photo above.

The top dipole is cut for 160 with a center frequency of 1.9 mhz formula is 468/1.9 X .96 works out to roughly 118 feet per leg.

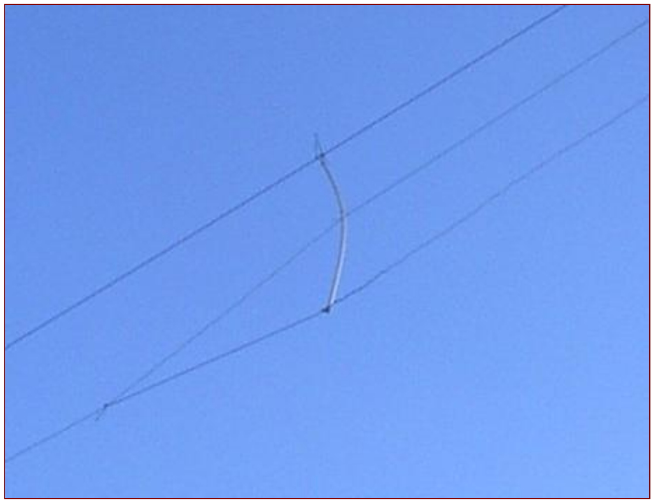
The center dipole is cut for 80 meters with a center frequency of 3.85 mhz.
The formula is 468/7.18 X 1.04 works out to roughly 63 feet per leg.
The bottom dipole of the multi band dipole is cut for 40 meters with a center frequency of 7.18 mhz.The formula is 468/7.18 X 1.04 works out to roughly 33' 10" per leg.

Note: Always arrange the dipoles with the lowest frequency band first, (on top), then the next higher frequency band under it and so on. You should end up with them in this order from the top:

160 on top
80   middle

40 bottom

The interesting thing here is if you look at the swr readings for each design frequency in the chart below this article, you will see that each band has a very low swr!



At the end of the 40 meter leg I used 78 inch length of 1/2 pvc for a spreader. I drilled holes and threaded the wire through for all three legs. I wrapped the 40 meter leg around the pvc and secured it with a small cable clamp. See photo above.

See photo above. At the end of the 80 meter leg I used a 40 inch piece of 1/2 inch pvc for a spreader, drilled holes through it and threaded the wire through for the remaining two legs.
I wrapped the 80 meter leg through the pvc and secured it with a small cable clamp.

At the end of the 160 meter leg a piece of 1 inch pvc was used to secure the leg and dacron rope was used to a tie point, any available tree or post will do. I sealed all of the connections with electricians liquid tape.

As you can see by the chart below, the harmonics work on 15 meters as well.

Although the analyzer shows a good VSWR on two meters I doubt if it can access any repeaters. I never tried.

Same goes for six meters although with that huge a capture area it may be a good receive antenna for that band.

On the air reports have been good.

I hope this will help anyone trying to experiment with this antenna for the low bands.

So there you have it....Four bands, one feed line, no antenna coupler required, and 15 meters as a bonus on the harmonics. And with the optional 20 meter band addition, you can have 5 bands all working well...see 20 meter additiion information below.

Remember that this fan dipole was designed for the 160, 80 and 40 meter bands. In the chart below you will notice a very low swr on each of these bands with red numbers! It also appears that many other bands may be used with a tuner.

Frequency vs R, X and VSWR Chart
(Notice the swr readings for the design frequencies of 1.91 - 3.86 - 7.18mhz!)

freq mhz	R	X	VSWR
148	41	14	1.4:1
144	46	17	1.4:1
54	58	27	1.6:1
53.5	76	38	2.1:1
50.38	45	31	2.0:1
29.7	16	6	3.1:1
29.37	39	29	1.9:1
28.86	66	36	1.9:1
28	20	8	2.7:1
24.99	16	12	3.3:1
24.89	16	17	3.2:1
21.45	59	25	1.6:1
21.03	69	25	1.7:1
18.17	120	77	3.3:1
18.11	77	78	3.2:1
14.35	14	9	3.6:1
14	71	46	2.2:1

10.15	**10**	**13**	**5.0:1**
10.1	**10**	**9**	**4.9:1**
7.3	**25**	**1**	**1.9:1**
7.18	**58**	**5**	**1.2:1**
7.12	**52**	**35**	**1.9:1**
4	**13**	**6**	**3.5:1**
3.91	**31**	**22**	**1.9:1**
3.86	**56**	**53**	**1.1:1**
3.82	**34**	**24**	**1.9:1**
1.96	**67**	**36**	**2.0:1**
1.91	**50**	**24**	**1.3:1**
1.86	**36**	**28**	**2.0:1**

Click here for the Harmonic relationship chart for this antenna for all bands by N5JNX.

Adding the 20 Meter addition as an option!

Just as an experiment, I added a separate 20 meter addition to the fan dipole.
I now have, 15/20/40/80/160 meters on one antenna

20 meters worked exactly as the others.
Formula used : 468/freq X 1.04

End Result Band Width for the 20 meter addition

Freq	R	X	VSWR
14.502	25	3	2.0:1
14.177	61	0	1.1:1
14.000	45	14	1.3:1

Spacing at feed point was identical to the 3 band version, six inches apart.

Further experimentation.

Maybe later, I will try to add 10 meters but the FAN configuration is starting to get out of whack with that many wire elements on one antenna. I may have to space the 10 meter feed point 12 inches from the 20 meter feed point to try and make it at least a 45 degree dipole.

Side by side comparisions on recieve show a 10 to 12 db less than the Mosley TA33 at 75 feet, about two S units less than the beam, so it is as it should be.

So there you have it....Four bands, (5 if you add 20), one feed line, no antenna coupler required, and 15 meters as a bonus on the harmonics with the designed bands having very low swr!

Try it! 73 - KJ4IIF

Basement Techie

Issue #2 – Spring, 2013

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Table of Contents

Finding Parts & Stuff

Welcome to the second issue of Basement Techie. I received a lot of feedback from the first issue, and would now like to thank everyone who took the time to let me know what you thought about our first issue. From the feedback I received, there were two things that were on the mind of most of you who wrote in. They were contributing to the magazine, and finding parts for your projects.

I am always looking for contributions to Basement Techie. I'm mostly an RF guy, so the majority of the articles are going to have that slant until some contributions come in. I'm interested in any DIY techie-type stuff: electronics, robotics, electronic security, computer hardware and software (programming), Arduino, Raspberry Pi, SDRs, or whatever! Send it in!!! While I can't as of yet compensate anyone monetarily for their contribution, you'll get a few free issues or some advertising space if you have a business or product you'd like to sell.

The best place I've found stuff for my basement techie experiments has been hamfests and surplus stores. Wildflower, on the other hand, has good luck dumpster diving, curbside scrounging, and checking out the local Goodwill stores. Both of us do well finding assorted random bits at the Dollar and Odd-Lot/Job-Lot stores, and Harbor Freight has been good to my friends and I. Look around your area, and you'll find stuff!

Listening Post

I would have hoped that by now you have done some research on sites like EHam, found some older equipment models with favorable reviews, and acquired gear. There is a lot of good stuff out there, and to mention it all would be impossible. As a rule of thumb, if most of the reviewers thought favorably of an item then it's OK. Likewise if everyone had panned the item then you want to steer clear. Mixed reviews probably mean it's OK, but caveat emptor. I don't put much credence in online reviews because I don't know the background or agenda of the reviewer. I don't put much credence in magazine reviews because magazines sell advertising to the companies whose equipment they review. I ask the fellow interceptors I know personally, and get their take on a particular toy I might be interested in because I respect their opinions and they don't have any agenda. Then I try to play with one for a bit before making a decision. I like receivers made by Icom, AOR, Yaesu, WJ/CEI, GRE, and Sangean. Never did much with Kenwood, Bearcat/Uniden, Sony, or Grundig, but a few guys I know have had good experiences with the gear. Every manufacturer has put out a real piece of shit at least once.

I have previously mentioned the Radio Shack PRO-2006. This was the latest model in a series of GRE manufactured, Radio Shack branded scanner receivers from the so-called "Golden Age" of VHF/UHF communications monitoring. Previous models included the PRO-2004 and PRO-2005. This series was immortalized by the late Bill Cheek, aka "Dr. Rigormortis", who published a series of books detailing various scanner modifications that were focused around the PRO-2004/5/6 series. After the PRO-2006, Radio Shack marketed the PRO-2035 and PRO-2042. These scanners were also made by GRE, and Cheek thought them to be the next generation '2006. There is some mention of the PRO-2035 and PRO-2042 in The Ultimate Scanner (Cheek 3) and in later issues of World Scanner Report. I've seen these models sell for anywhere from $75-$150 on Epay, and offered for a slightly lower amount at local hamfests. For general-purpose VHF/UHF monitoring they are all good units.

Many times receiver selection is determined by what you find cheap at a hamfest. One example is a Radio Shack PRO-38 that cost something like $10. Before you Google it thinking I've disclosed some hidden gem kept secret by professional interceptors, it's just a 10-channel hand-held with basic VHF-low, VHF-high, and UHF bands coverage. Why buy it then? The price was right and it works fine for keeping a close eye on a

couple local frequencies. A similar purchase was made by one of our Southwestern brethren who found a Bearcat BC-155 at a yard sale for 7 bucks. A $40 (talked down from $70) Hallicrafters S-77 is more than good enough for AM and Shortwave broadcasts. It also adds a little class to the listening post. A curbside (read: free) Lafayette HE-51 is fine for watching that one VHF-low band frequency you have an interest in. Our esteemed editor found a surplus VHF-high band spook receiver system that sported a nice Marantz cassette recorder. It had apparently escaped the interest of all the other hamfest attendees during the course of the morning. The entire rig is built inside a Pelican case. If you keep your eyes and mind open, you will find neat shit like that.

One type of receiver we look for when cruising the swap meets is the surplus mil-spec surveillance or "spook" receiver used in SIGINT applications. The most famous brands are CEI and Watkins Johnson. Other noteworthy brands are Nems Clarke, Reggco, Racal, Astro, and Norlin. We also look for adjunct equipment such as demodulators, digital frequency readouts, spectrum display units (panadapters), and tuners. If the price is reasonable we grab anything of this type we find at the swap meets, even non-working "parts" units. For the most part this equipment is overlooked by all but a select few monitoring "hobbyists". This gear is top of the line, and originally cost orders of magnitude more than the standard asking price at the hamfests. It also has certain features that you don't find in the consumer-grade scanners and shortwave receivers. We will discuss "premium receivers", as they are known in hobbyist parlance, in future issues of Basement Techie.

The VHF/UHF antenna of choice for many interceptors is the discone. Radio Shack sells one, although the preferred model is the Diamond D130. The cost however may be prohibitive to some budgets. Radio Shack sells their Cat#20-176 ground-plane antenna for $30 that works from 108-1300 MHz., optimized for 152-470 MHz. Many interceptors have started out with one of these. It works well enough, but I found it to be lacking on the VHF-low band due to its small size in relation to the wavelength involved. Many interceptors elect to build their own antennas. Indeed, a simple 1/4 wave groundplane antenna can be made out of coat-hanger wire and a SO-239 connector for a few bucks. Radio Shack sells chassis-mount SO-239s for $4, and you can likely find better-quality ones elsewhere for less than that. Just about any chassis-mount female RF connector can be used to make this antenna. Many interceptors eschew the SO-239 in favor of a BNC or N-type connector. Some even just forgo the connector entirely and solder the elements directly to coax.

Ideally, you want to get your antenna outside, but in some instances that may not be possible. In that case a simple vertical dipole made out of a length of coaxial cable with the appropriate RF connector on one end will do an adequate job. If you are making either an indoor coax dipole or a quarter-wave ground

plane antenna out of coat-hanger wire, you will need to determine the length of the antenna elements. Use the following formula: L=2808/F Where L = Length in Inches, and F = Frequency in MHz.

To make a coax dipole, strip off the cable jacket to the length you determined from using the formula. For example 155 MHz. would be 2808/155=18.1 inches. 18 inches would be close enough. Take a small flat-blade screwdriver, make a hole in the braid where the jacket ends, and pull the center conductor through. You now have a dipole antenna that is 18x2=36 inches. That is a half-wave length for 155 MHz. and the proper dipole length for that frequency. For the ground-plane antenna you would solder an 18 inch length of stiff wire (coathanger) to the center conductor as your vertical element, and four 18 inch lengths at 90 degree intervals to the braid. A SO-239 or similar chassis connector is perfect for this as you have a center solder connection and four chassis mount holes for the ground-wires. If you can find a metal pan or pie tin that has a circumference equal to or greater than a 1/4 wave length at your frequency of interest, you can attach a chassis-mount connector to it, and use the pan as your ground-plane. Many interceptors use that arrangement with mag-mount antennas inside.

For HF (shortwave), most interceptors I know use either whatever HF ham antennas they already have installed, or go with the traditional inexpensive longwire antenna as long and as high as they can get it. In limited space situations, I've done pretty well with Hamstick-type mobile antennas attached to a counterpoise. While these antennas are designed for use on a specific amateur band, they also work well enough for Rx on frequencies adjacent to their particular ham band. One particularly good antenna I've used is the Barker & Williamson AP-10 apartment dweller antenna. The AP-10 has been discontinued, but MFJ has their MFJ-1622 that is an equivalent.

Your coaxial cable can make or break your antenna installation. Do not use cheap hi-loss coax! For short runs at UHF and short to medium runs at VHF use nothing less than RG-8X or preferably RG-213. Hardline would be better, but then you are getting into a higher cost. There is a decent low-cost alternative. Many savvy interceptors use RG-6 type coax used in CATV and satellite TV installations. The stuff is fairly low-loss at frequencies up to 1 GHz., and the mismatch of 75 Ohms versus the usual 50 Ohms in comm gear is minimal. Some hams have even used it for transmitting and reported no issues. For receiving setups it'll work just fine. I picked up a 100-foot spool of it from a local odd-lot/job lot store for only $10. It comes with F-type connectors on it, but adapters are readily available for PL-259, BNC, and other common types. You can also take advantage of the inexpensive splitters and antenna switches available via common retail channels.

Scrounge-Tek

I try to remember how as kids my buddies and I used to build almost anything from material scrounged and adapted from scrap and nature, and how in the '60s we furnished our apartments with tables made from old cable spools and book-shelves made from milk crates or cinderblocks and scrap boards. The true survivalist is not a purist. You know the type, "It's gotta be authentic Special Forces Issue... It's gotta be authentic mountain man era gear... Ya gotta make it with stone tools and yer bare hands... Etc." Use any and everything available!!!

- Injun Jessie,
Cybertek Issue #17

Every Basement Techie I know keeps a collection of scrounged piece parts. The size and composition varies depending on the amount of space available and what they're currently into experimenting with. Sometimes we find something dirt-cheap at a tag sale, flea market, surplus store, or hamfest that looks interesting or potentially useful. The preferred means of acquisition is free via dumpster-diving or curb-side scrounging. At one previous job, the route to the dumpster was via the back of my service truck and I managed to score a decent collection of "obsolete" working and semi-working radio gear that was either put into ham use, traded to fellow techies for other neat stuff, or stripped for useful parts. When storage started getting a a little tight, items that were considered excess to needs were just given away. The stuff didn't cost you anything in the first place, and your buddies would reciprocate kind when they found something they knew you'd be interested in. That last part was always useful when you were running a little tight on cash or scrounging resources.

Whenever I start getting into a project, I take a trip down into basement and go through the boxes that hold my scrounge stock. Sure enough I found two items that I needed for some of the projects in Voice Of the Crystal and Impoverished Radio Experimenter. Some copper tubing I salvaged from an old propane stove installation had a fitting on it that after a little clean-up will make a perfect crystal holder for a home-built detector. Flare nuts aren't too expensive, only about 2 and a half bucks each. Still though the small parts add up in cost. The other item was an 8-pin octal relay socket from a box of assorted parts I rescued from previous job's dumpster. Actually was two of them in there. Those start getting a little more pricey at anywhere from $3 to $17 each depending on where you buy them from. My local source has them for about four and a half bucks. These three items would have been around $12, which is a quarter tank of gas for the car in these parts. Thanks to a little scrounging, they didn't cost me a dime.

Using mostly scrounged parts, I put together a working crystal radio set for AM Broadcast Band. How I did that is the subject of my next article...

A (Mostly) Scrounged Crystal Detector

A lot of crystal radio enthusiasts prefer the “soft” sound that comes from a mineral detector. The most common minerals used are Galena and Pyrite. After having compared my Galena detector to a 1N34 Germanium diode, I agree that the former does sound better.

Depending on where you live, you may be able to go mineral prospecting and find some Galena or Pyrite for free. I've seen both at various mineral shops costing anywhere from $1 to $7 for a small to medium-sized piece suitable for use as a detector. Being the middle of winter with likely prospecting locations under snow, I visited Nature's Art in Oakdale, CT. So far I have found them to have the best rock prices, and was able to pick up some small pieces of Galena and Pyrite for a couple Dollars each.

The holder for the crystal is a brass flare nut used in natural gas and pluming fixtures. I drilled and tapped it for three 6-32 machine screws used to hold the crystal in place. The holder was then soldered to a piece of flat Brass stock.

The cats-whisker assembly is made from a piece of thin music wire. It is held to a piece of copper-plated pipe strap by way of two nuts and a machine screw that I cut a slot in with a Dremel Tool and cutting wheel. Another piece of flat Brass stock attaches the assembly to the base.

The base is a small Lego box that my wife got me for Christmas. She says she found it at thinkgeek.com. Some machine screws and nuts hold the two assemblies to the base. I then removed most of one side of the lower box half (it slides into the upper) to make room for the two terminal posts that I attached to the upper half.

Finally, some 22ga hook-up wire was used to attach the terminal posts to the two assemblies at the top of the box.

The flare nut assembly is great for trying different minerals as a detector. The cats-whisker assembly works, but I'm not too happy with it. I'll try something different in the next version.

Useful Books To Have:

Voice Of the Crystal:
http://www.hpfriedrichs.com/bks-votc.htm

Impoverished Radio Experimenter:
http://www.youroldtimebookstore.com/category-s/2033.htm

A Trip To Goodwill

Goodwill stores get a lot of mention as a good source of materials. Some basement techies seem to have better luck at finding things than others, but like any other used merchandise source it's hit or miss. The general consensus is that the more frequently you visit, the better your "luck" is in finding stuff.

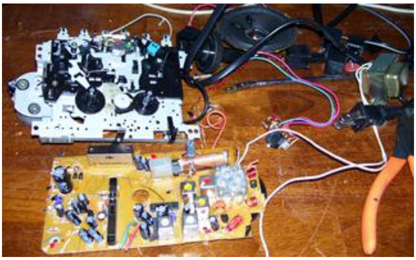
A couple weeks ago, I visited a local Goodwill store on a weekday, as opposed to my usual weekend schedule. My budget was a nominal $10, and I wanted to see what I could find that could be used for my experimentation. This particular Goodwill has been about average in yield for me. Many times I've left empty-handed, but when I have found something it was an above-average find.

My first find was this Radio Shack 200 channel police scanner, a PRO-2018, for $4. It came with its wall-wart power supply and was 100% functional. Right now it's scanning VHF aircraft band frequencies, and you can see in the photo that it was stopped on one of my local ARTCC enroute frequencies. There is still enough analog VHF/UHF traffic around here to warrant grabbing another inexpensive police scanner, and they also make good test receivers for various projects, especially considering what I found next.

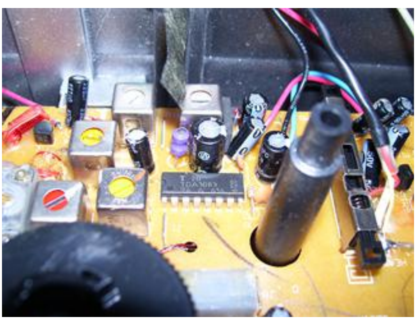
This $3 1970s vintage walkie-talkie is unique in that in addition to being a 49 MHz. band license-free transceiver, also receives the 27 MHz. CB channels. I just grabbed it to add to my radio collection, although it could be used for monitoring the 11 Meter band, or as the transmitter in a one-way telemetry link on 49 MHz. The police scanner I purchased along with this unit would serve well as the receiver. While this one was in working condition, even if not 100% functional the telescoping antenna alone would have been worth the $3.

This small portable AM/FM cassette stereo cost $5 and was 100% functional. It is to be dismantled in order

to show you what useful experimenter parts are inside electronic gear of this type. When buying stuff for deconstruction, ideally you want the cost of the item to be less than that of the individual components. For recent-vintage solid state gear like this, $5 is a good target price.



As you can see, I definitely got my money's worth out of it. I salvaged an AC power cord, 6V transformer, telescoping whip antenna, a cassette deck with motors, gears, and other mechanical bits, and a circuit board with some useful RF parts including an AM looopstick antenna, tuning capacitor, and some inductors.



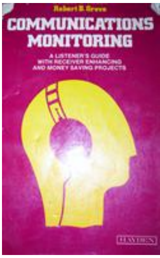
Here is a closeup of the receiver circuit board showing a TDA1083 integrated circuit. The TDA1083 is a One Chip AM/FM Radio with Audio Power Amplifier. Many hobbyists have successfully used this chip to make nice LF/MF receivers, and with some basic modifications, a standard AM radio could be slid up or down in frequency for a coverage of 300 KHz. To 3 MHz. Similar mods can be done on the FM side for coverage above the standard FM broadcast band where interesting things have been known to transmit.

If I had need for an inexpensive receiver covering those frequency ranges, I probably would have left the radio intact, and modified the RF components on the receiver board to slide the frequency coverage into the desired range. This trick can be done on most solid-state AM/FM receivers of recent vintage by spreading or compressing the coils alongside the tuning capacitor unit (the white/clear square plastic component). Determining which coil to adjust is as simple as tuning to a station located at the edge of the band of interest and touching the coils with your finger to see which one de-tunes the radio when it's touched. You then squeeze or expand the coil to lower or raise the frequency coverage and "walk" the station up or down the dial.

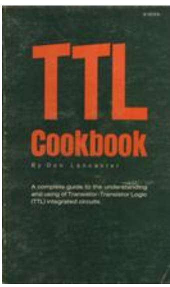
A very excellent set of directions on how to do this with an AM transistor radio to receive shortwave broadcasts is available in **Cybertek** Issue #9, "Doing a Radio". You can download from:

http://servv89pn0aj.sn.sourcedns.com/~gbpprorg/2600/TAP/cybertek/Cybertek_09.pdf

Another good reference to have is **Communications Monitoring**, by Robert B. Grove, ISBN 0-8104-0894-0.



You can find copies on Amazon for only a few bucks. This is one of the first books I bought when I started this hobby. Among the other useful information it contains is a set of instructions on how to tweak consumer AM/FM portable radios to go out of band, and several simple electronics projects to enhance your monitoring activities.



While on the subject of books, although I did not find anything interesting on this last trip, I have often found useful electronics and engineering books in my local Goodwill and Savers stores. The best stores for books are the ones in college towns. It was one such store where I found this copy of the classic **TTL Cookbook** by Don Lancaster.[1]

Used equipment sources are hit or miss, and you need to frequent them on a regular basis to find the good stuff. While you find neat stuff, most of what you'll come across is common stuff you can buy cheap and kit-bash for your particular purposes, much like I did to that portable stereo.

1 http://www.tinaja.com/

Old-School Wireless Networking

I was surfing a Yahoo Group on survival communications, and came across a post by a member who found an old PC PDA, and was wondering about its usefulness for packet radio. The poster came across this link:

http://www.qsl.net/o/oe9fwv/packet.html

A good discussion followed afterward, and I was surprised how many old-school Guerrilla-Net RF hackers were still out there.

Back in the days way before the Internet, ham radio operators were doing data communications over the air. When I first got my ticket, it was just straight up Baudot and ASCII RTTY at speeds from 45.45 to 300 baud. Most of the activity was on the HF bands, with occasional activity on VHF. One of my elmers was a hardcore RTTY enthusiast, but when I went down to Varick St. in 1984 and passed my Technician Class license exam the latest thing in digital ham communications was 1200 baud AX.25 Packet Radio on the 2-meter band. Shortly after I got my first rig, I bought a used TNC and started surfing the AX.25 networks. Hams had a VHF/UHF wireless digital network on the East Coast

extending from Maine to Florida, and inland as far as the Mississippi River. Portions of that network are still active to this this day as Eastnet:

http://www.eastnetpacket.net/eastnet.html

The biggest use of AX.25 these days is a system on 144.390 MHz. called APRS: Automatic Packet Reporting System. The APRS website is http://www.aprs.org/. According to the website, APRS is *"a two-way tactical real-time digital communications system between all assets in a network sharing information about everything going on in the local area."*

Besides APRS and the occasional AX.25 network such as EastNet, the frequencies[2] used for Packet Radio are pretty quiet. Used TNC[3]s are commonly and cheaply available at hamfests, as well older 2-meter radios to hook them up to. This means plenty of equipment and space for groups of technological experimenters to set up their own long-distance wireless networks. **The bands are out there waiting to be used.**

Besides 2-meters, there are other underutilized ham bands that you can use for Packet Radio. Two of the other popular bands are 6-Meters (50-54 MHz.) and 1.25-Meters (222-225 MHz.). The 1.25-Meter band is used heavility for point-to-point network links, where 6-Meters seems to enjoy a lot of long-haul work.

If you were doing Packet Radio with a few friends over a bit of distance, and wanted an alternagtive to 2-Meters, then the 6-Meter band might be the place for you.

I found this 6-Meter Band data radio at a recent hamfest. While not as extensive as 2-Meters, there is still some activity there. The Kentucky Packet Network at http://kypn.wordpress.com/ has a lot of good information on it. However the neatest thing I've found for 6-Meter Packet is an application for an APRS Meteor Scatter Email System. See http://www.aprs.org/meteors.html.

Those of you who would like to experiment with TCP/IP over the air are also in luck. Check the following links:

Getting Started With TCP/IP On Packet Radio - http://www.febo.com/hamdocs/intronos.html

Linux AX.25 Configuration - http://www.febo.com/packet/linux-ax25/index.html

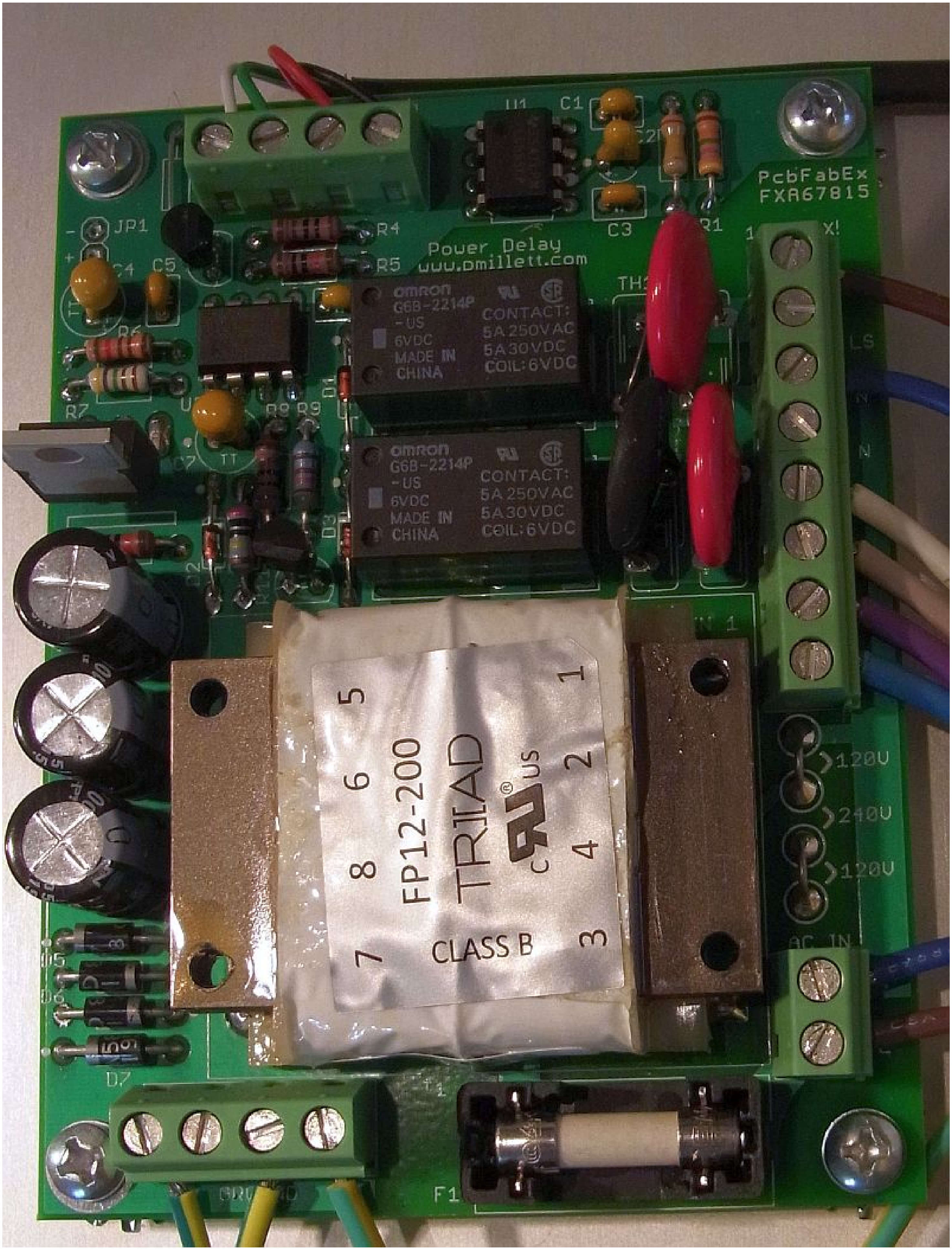
There is a lot of good & cheap used/surplus equipment out there, the frequencies are mostly dead, and the test is easy to pass. Why not give it a try?

2 145.01, 145.03, 145.05, 145.07, and 145.09 MHz.

3 TNC – Terminal Node Controller

[DIY Audio Home](http://www.pmillett.com)

An AC power delay circuit


U1
C1
C2
C3
R1
R4
R5
R6
R7
R8
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C4
C5
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TRIAD
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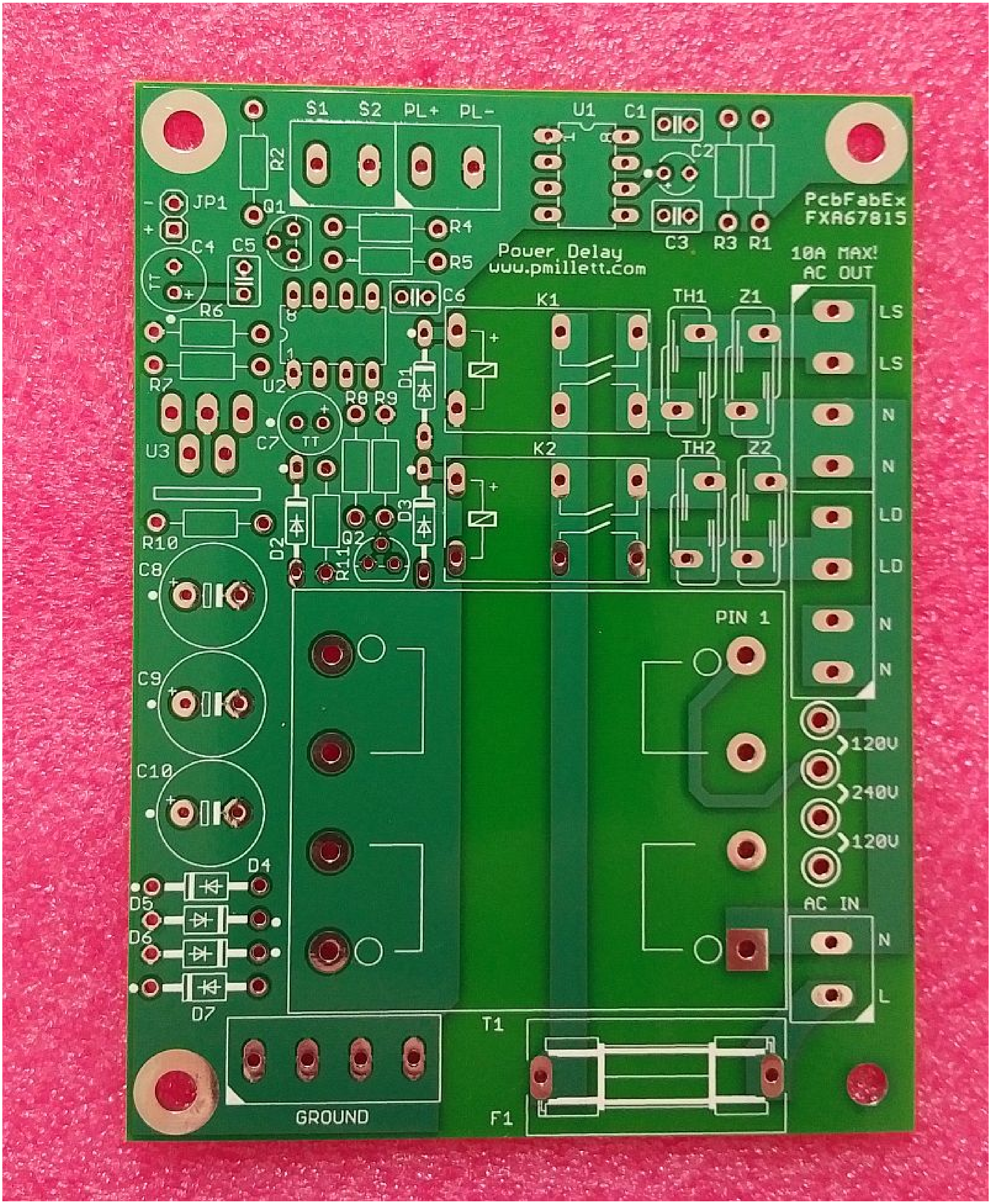
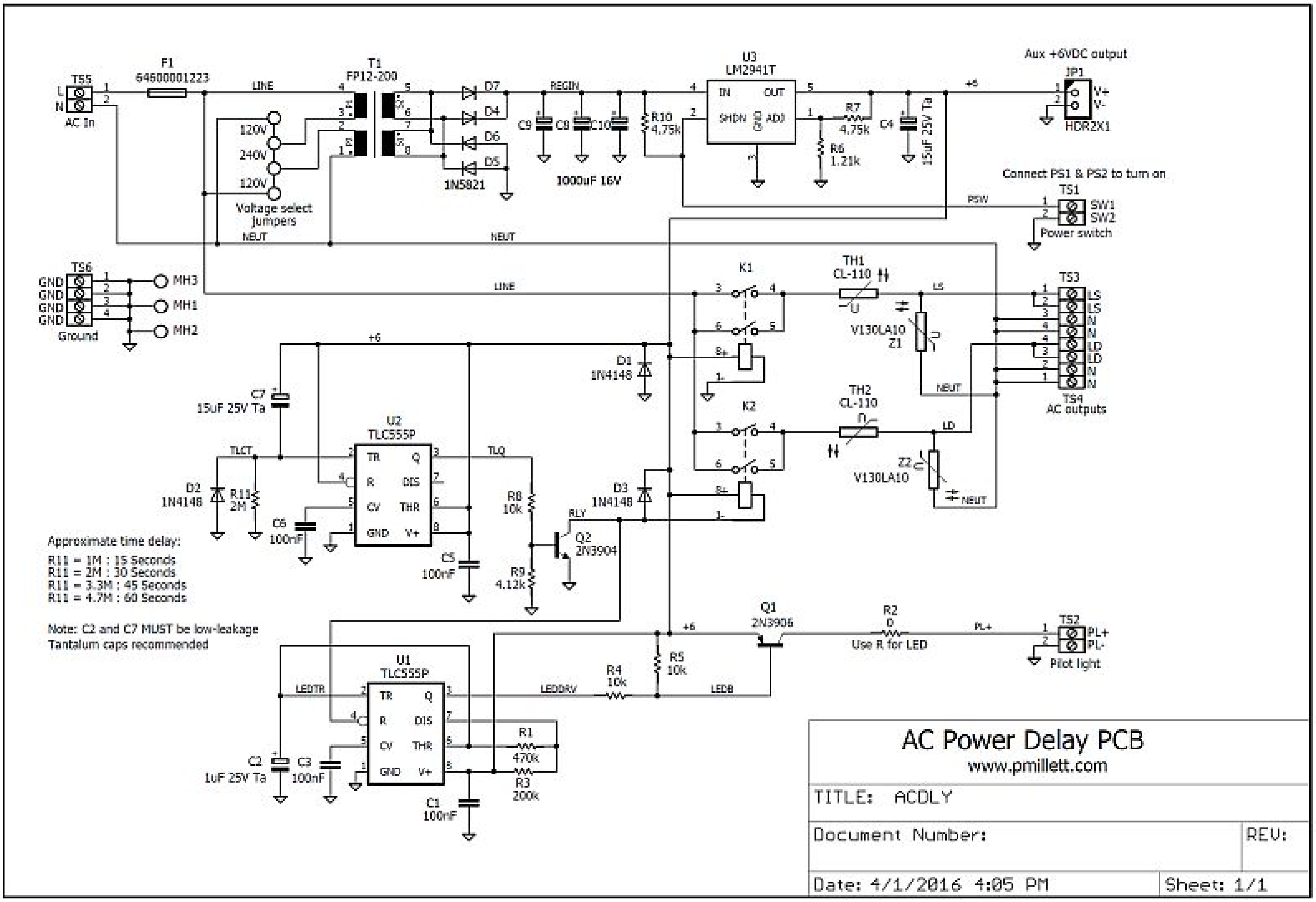
240V
120V
AC IN
D7
F1



For the PL-177 amp, I needed a circuit to delay the application of B+ power until the tubes have warmed up.

Since I used a switching power supply for heaters and a separate HV supply, I wanted to switch the AC power to the two systems, as opposed to messing with the high voltage B+. So I designed this:



[(Download it in PDF)](#)

It is similar to the muting relay [delay circuit](#) I built earlier, but it has larger power relays that can switch up to 10A at line voltage. It also integrates a small "housekeeping" power supply, to run the timer and power relays. It also integrates inrush limiters and MOVs. Sorry, I don't have a parts list (BOM) completed, but it is pretty obvious from the schematic. The power transformer is a Triad FP12-200, and the power relays are Omron G6B-2214P-6VDC.

I will make these PCBs available in [my eBay store.](#)

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The $4 Special Antenna

by Joe Tyburczy, W1GFH

(Used with his kind permission)

Sure, you can find "all-band wire antennas" for sale in the back pages of Ham magazines costing $150 or more. But beware: *Marconi spins in his grave every time a ham buys an aerial instead of building it.* The plain and simple truth is that wire antennas for the HF bands were intended to be *hand-made* and not store-bought.

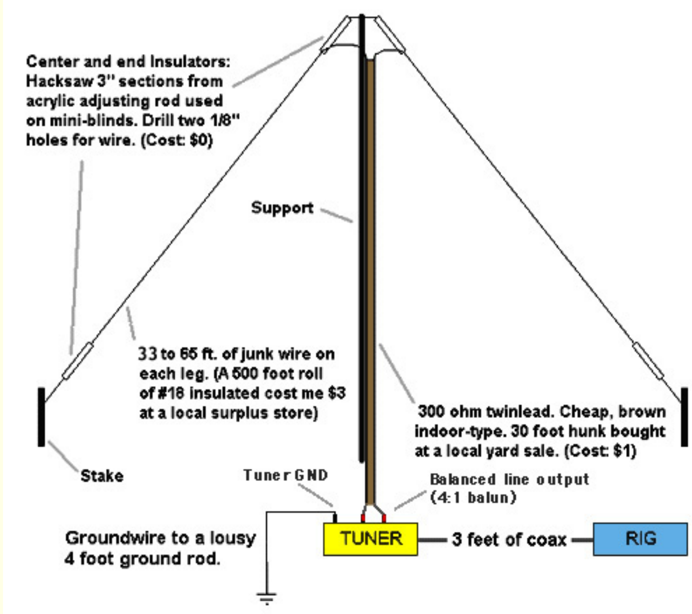
Untold generations of intrepid Radio Hams have fashioned their own equipment out of spit and bailing wire. Do you think the spark-gap dudes of the 1920's just went out and bought ready-built G5RV's from HRO or AES? No way! They slapped together aerials out of bedsprings, chewing gum, and frozen cow poop. For them, every day was Field Day. I think that home-built antennas should be awarded 10 db of "honorary gain" simply by virtue of their ingenuity. And in this world of microprocessor controlled micro-rigs, constructing one may be your only chance to build something and actually see it work on the air. Think about it.

RadioWorks, Alpha-Delta, MFJ, B&W, Van Gordon, W9INN, and W7FG...nothing wrong with the wire antennas they sell. But buying one is no substitute for "rolling your own". Don't be overawed by their advertising rhetoric. You can make an antenna every bit as good as theirs, and even better in many cases.

Just Do It

Don't be intimidated by SWR, either. Your rig will not blow up and kill you. Most modern rigs will politely refuse to transmit into a really bad match. A perfect 1:1 SWR is for sissies, anyway. All *real* hams have conducted perfectly good QSO's at 3:1 (or more) at some time or another. You may be surprised to know that the vast majority of hams didn't fret about SWR until after WWII when coax cable and SWR meters ("SWR Bridges" as they were first known) became available on the commercial market. Before that time, you simply cut your antenna to frequency, loaded the transmitter final for best output according to the plate current meter, and that was that.

I am a big fan of "balanced line" (twinlead, open wire line, etc.) vs. coax. By using balanced line and a tuner you can have one, single-element antenna that works well on all bands. You can't do that as easily with coax. The basic "W1GFH $4 SPECIAL" shown below is a variation on the type of versatile skyhook I've been using for years.



Now at this point, some of you may be looking at the diagram and muttering, "Jeez Joe, that's just a dipole fed with twinlead and used with a tuner". Well of course it is. Virtually all antennas are "di-poles" (i.e. "two sides") in some form or another. This one just happens to be made from low-cost materials.

I won't go into the theory here, but trust me: balanced feedline, properly used, does not "leak" RF and is less lossy than coax. I've tried the commercial 450-ohm ladder line, but prefer 300-ohm TV twinlead, and the cheaper the better. Radio Shack TV twinlead is ideal. Home Depot has some good stuff, too. Forget all the obsessive junk about standing waves, impedance and velocity factor. What you really need to concentrate on is getting an interesting set of *antenna insulators*.

Hang It Up

Back during the disco era when I first got on the air, I got a pair of really cool antique *pyrex antenna insulators* from a flea market table in Derry, NH for 25 cents each. They looked like the kind Hiram Percy Maxim used in 1910, and seemed able to pull in exotic DX all by themselves. The other day I found out that Radio Shack wants $5 apiece for insulators made from some kind of white plastic crap. So I improvised my own by sawing up pieces of an acrylic adjusting rod from a discarded miniblind. I think Hiram would've been proud of me.

Hang the center of the antenna from a tree limb, or use a support as pictured. The exact height of the antenna's feedpoint is not crucial. The higher, the better. 20 feet might be considered the minimum. 60 feet is ideal. However, in the real world, 30-50 feet is average.

For the antenna wire itself, virtually anything will work, but something close to #18 stranded/insulated is ideal. My favorite stealth antenna material is magnet wire. You can dig this out of an old transformer or even a busted loudspeaker's coil. This ultra-thin stuff is truly INVISIBLE to neighbors and wives alike, and it'll handle 100 watts, no sweat. If you need to keep a low profile, try it as a long longwire, end-fed from your tuner's "wire" terminal. (Be sure and ground everything in the shack like crazy) No trees in your yard? Use a sock filled with sand for a weight and hurl the far end of the wire onto a NEIGHBORS roof or tree. (I would advise doing this at night. If you are caught, claim you are "trying out an old FARMERS ALMANAC recipe to keep bats away". People universally hate bats, and love farmers) If you can't possibly scheme to get your wire more than a dozen feet off the ground, try flinging a few hundred feet of the magnet wire all around the yard in a big loop (find out measurements in the ARRL Handbook or Google "80 meter loop antenna"). Loops can perform satisfactorily at low heights. And remember, don't fuss too much about SWR. A little

mismatch is good for you and builds character.

The ends of the antenna will be "hot" with RF, so it's a good idea to keep them out of reach of people and pets, say, at least 10 feet above ground. However the antenna will still function if you bring the ends down closer to the ground.

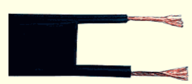
Love Your Tuner

An antenna tuner with a balanced output (internal or external balun) is a must. Using one is a simple matter of adjusting capacitance and inductance for the lowest SWR on a given frequency. Always begin your adjustments at low power, increasing to full power only when you have a reasonable match. At first, you may think it's inconvenient and old-fashioned to manually tune your antenna every time you change frequency, but you soon discover the unique satisfaction of tweaking the variable caps and watching the reflected power dip lower as the received signals grow a bit louder in your receiver. It's "real radio".

My first tuner was a 1980's wood-grain cabinet style MFJ-941 I got at a swap meet for $15 a long time ago and featured an internal balun and connections for balanced lines on the back. Make sure YOUR tuner is an outboard manual type antenna tuner such as this, and not an "automatic" or internal tuner that is a pushbutton feature on many modern rigs. Because they must use small, light-duty components, these built-in tuners are typically limited to handling mis-matches of 10:1. The mis-matches YOUR feedline will be seeing can be as high as 100:1. But don't worry. The he-man sized coils and air-variable caps in a typical outboard tuner will handle it just fine.

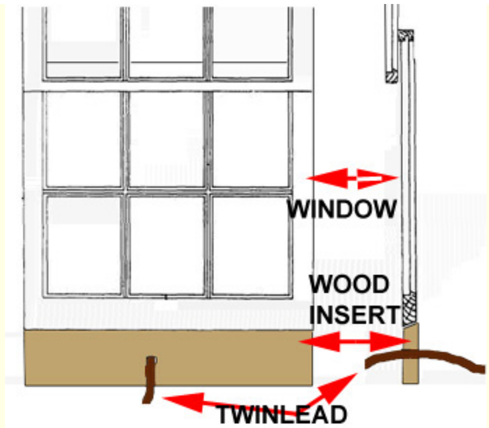
Don't believe the folklore about MFJ tuners being junk. It's true, they are cheaply made and their Quality Control is spotty, but the majority of them work perfectly OK if they aren't abused. So do old Dentron's, Drake, Vectronics, Nye Viking, etc. A link-coupled balanced tuner arrangement like the Johnson Matchbox would be even better, but use what you have. Or make one. Ham radio (unlike some other hobbies) isn't a competition to see who can own the best or most expensive gear. *The idea is to get on the air with what you have or can afford, enjoy your self making contacts, and as time and money permits, try something else.*

I had a 65ft. per leg version of this antenna working in Massachusetts, and it'd tune up on all bands 80-10. At my Burbank, California QTH, I used a 35 ft. per leg version, and it tuned up on 40-10. By the way, you'll notice it's an inverted vee --- a real advantage if you don't have room for a full-sized dipole in your yard. If you still don't have room, bend and angle the legs to fit the space you've got. Antennas gently bent into Z-shapes still work fine!

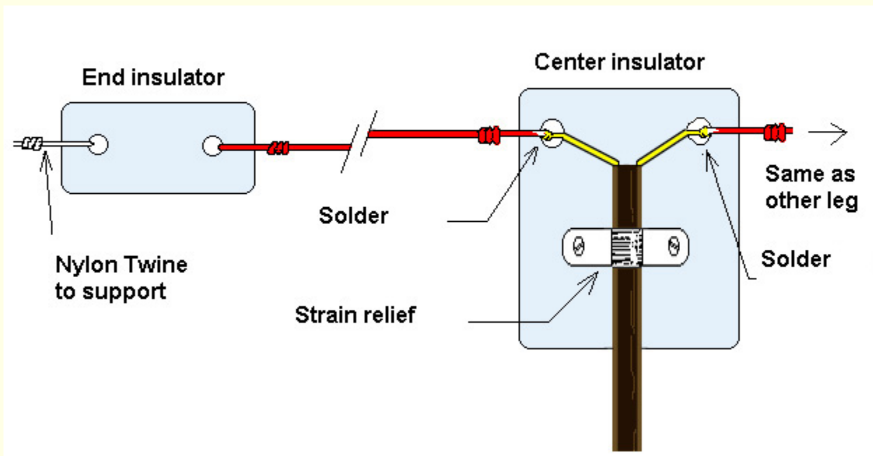


The Magic Of Twinlead & Wire

The uncut feedline comes straight in thru a clever window sash arrangement first used by hams in the 1920's. (See drawing below) Alternately, you can attach the wires to feed-through bushings (which can be anything from two steel bolts...to a pair of banana jacks end-to-end) set into holes in the wood sash or a glass pane (or a plexiglass panel). 300 ohm twinlead only needs about 2" separation from metal objects in its path. Unlike coax, its "gotta be free" -- don't coil it up, kink it, bury it, or lay it on the ground. Gently brushing against tree limbs or tied to non-conductive surfaces like wood or plastic is OK. The 100 watt output of most transceivers makes TV twinlead a safe and practical choice, but a number of hams have used it successfully with power ranges up to 1KW PEP. You can obtain or construct an external 4:1 balun to make the transition from your twinlead feedline to a short length of coax, then bring the coax into the house via a single feedthrough hole if you'd like.



OK, back to construction for a moment. Here's a variation of the $4 Special that uses center and end insulators made out of plexiglass sheet. But you can improvise yours out of an old DVD, sawed-up PVC pipe, a plastic Coke bottle...or anything you'd like.



If you want to be adventurous, try using 110VAC lamp cord ("zip" cord) as a feedline. Yeah, it'll work as a crude balanced line, believe it or not. Impedance varies, but is usually "close enough" to work. And that reminds me...

**Ham Tradition**

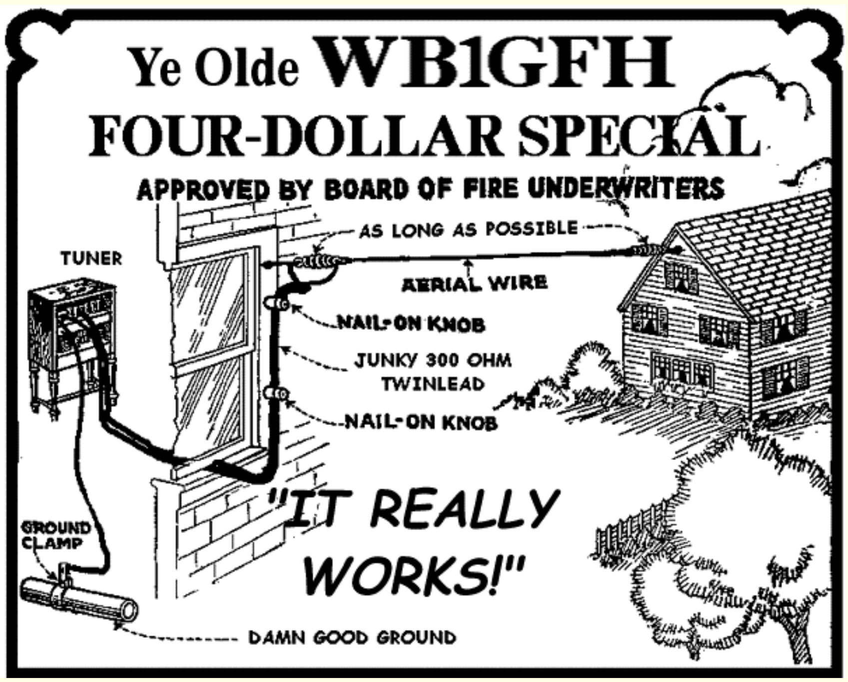
Today's new hams have been cheated out of the constructive experience of being harangued and berated by crabby old "Elmers" preaching about how they did things in the "good old days", so I am taking it upon myself to provide you with a taste of it here.

There is very little experimentation among hams these days, and most stations are cookie-cutter duplicates of one another: same antenna, same Japanese transceiver, same 599 QSO. This is not the ham radio tradition of old. In the 1930's and 40's you might find one ham using twisted bell wire as a feedline. Another might be using bare electric fence wire on ceramic standoffs nailed to wooden planks. Another might be using copper tubing. Or pieces of metal roofing. Or auto ignition cable. Or tin cans soldered together. If you looked at their stations you'd discover a wealth of marvelous invention, idiosyncratic design, and an incredible ability to press available objects and materials into service. During the 1960's, groups of hams would get together to swill cases of beer and then make antennas out of the discarded cans by soldering them together, end-to-end. *Improvise. Experiment.* Take notes of what works and what doesn't. This is what ham radio is all about.

When **you put up your antenna is also crucial. I must mention here the importance of what many early hams called "antenna weather". That is, snow, sleet, freezing rain, or combination of all the above. It has been proven time and time again that any antenna installed in conditions better than abysmal will not function worth a darn. Or, put another way, it takes bad weather to put up a decent antenna. Dark and cold New England winter days are ideal for this activity. Any antenna erected on such a day will inevitably produce miracles.**

Many of you will recognize THE $4 SPECIAL'S design as the venerable "double zepp" aerial, a variation of the "end-fed Zepp" -- the skyhook responsible for the dramatic Hindenberg tragedy in Lakehusst, NJ. It seems the blimp's radio op decided to work a little DX while waiting for landing clearance. He sent out a few CQ"s. Unknown to him, the ladder line had twisted in the breeze, shorting the bare conductors. A brilliant spark flared up, and.....well, that's another story altogether.

To see an "end-fed Zepp" version of the $4 Special, just look below.



Alas, I never had a 100 foot tower to hang this antenna from. The one in Mass. was up 50 ft. and worked what I considered terrific DX. The one I have now is only up 30 ft. and gets good to average results. It won't outdo a Yagi at 100 feet. Very few things will.

But for $4....who can complain? 73! Joe.....WB1GFH

ADDENDUM: March, 2005

Since writing this article in 1998, I've gotten a lot of questions.

Some are new to antenna tuners. There's no mystery, using one is very simple. It's a matter of adjusting capacitance and inductance for the lowest SWR on a given frequency. There is a quick tutorial at:

http://www.hamuniverse.com/tuner.html

Others are curious about the end-fed Zepp. I suggest you go to L.Cebik's fine page on this subject for an explanation of the practicalities of such an antenna:

http://www.cebik.com/gup/gup12.html (Log in required)

If you are a beginner, you'd do well to read all of Mr. Cebik's antenna articles. They are a wealth of practical knowledge.

Many want to know about feedline lengths. Is there any 'ideal' length? Yes and no. Some feedline lengths will present an extremely high impedance to the tuner on certain bands. Each installation is different, but here are some rough guidelines that may help:

Start by trying a feedline listed in the lengths below. It may take some trimming or adding of feedline to work well on the range of bands you want to cover.
The worst possible feedline lengths are shown in brackets:

If Ant is 120 ft per leg it will cover 160 thru 10 meters.
Feedline of 40-70 or 150- 190 feet suggested.
[Avoid lines around 120 or 240 ft]

If Ant is 65 ft per leg it will cover 80 thru 10 meters.
Feedline of 25-40, 80-100 or 140-160 feet suggested.
[Avoid lines around 60, 120, or 180 ft]

If Ant is 33 ft per leg it will cover 40 thru 10 meters.
Feedline of 40-50, 70-80, 100-110 or 130-140 feet suggested.
[Avoid 30, 60, 90, 120 ft]

Many thanks to Joe, W1GFH for allowing us to share his project...N4UJW

Recent site activity

Fix:under extrusion:long move or retraction
edited by he yl

3D Printing
edited by he yl

Restoration An Tektronix 464
edited by he yl

Tektronix 485 Attenuator
edited by he yl

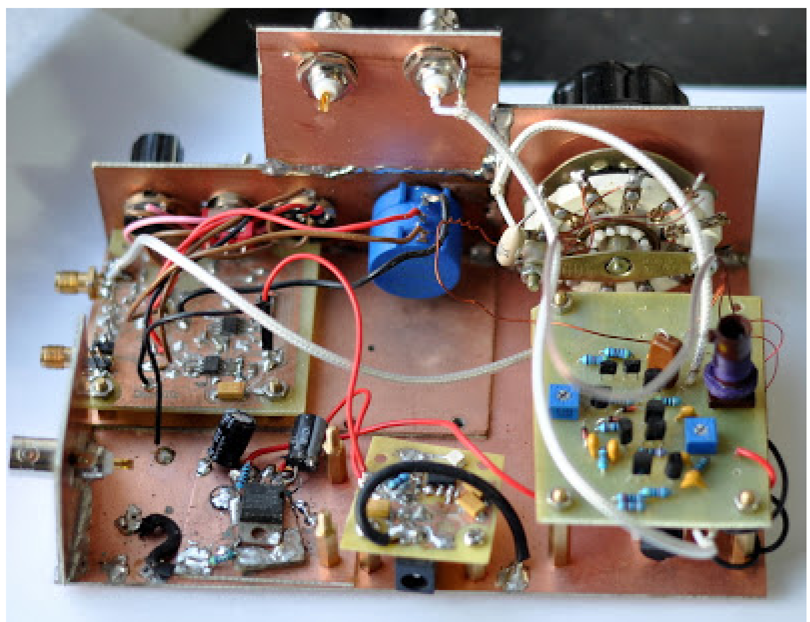
View All

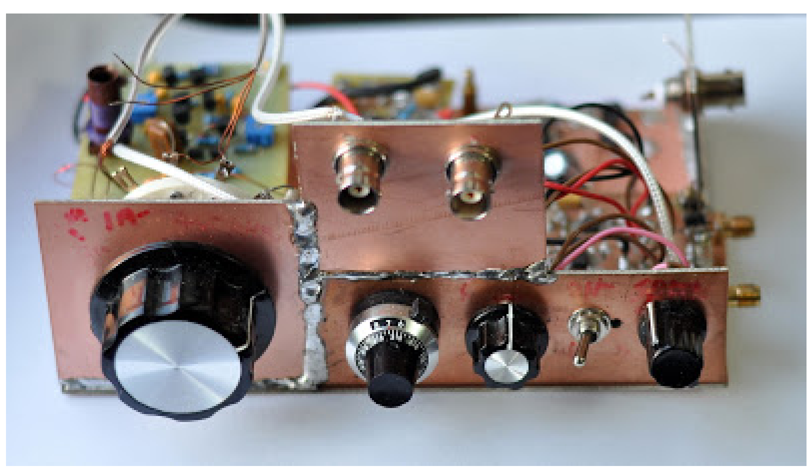
RF Homebrew Instrument >

Sweep: boostrap sweeper

updated @12/23 2012

here is the final project , very ugly but very useful. the project contain a ramp generator and a VCO. the ramp is Ramp: linearity ramp generator .





@update @ 2013/10/13, new box, remove the ramp generator from the VCO, use ramp output from sweep: sweep signal source

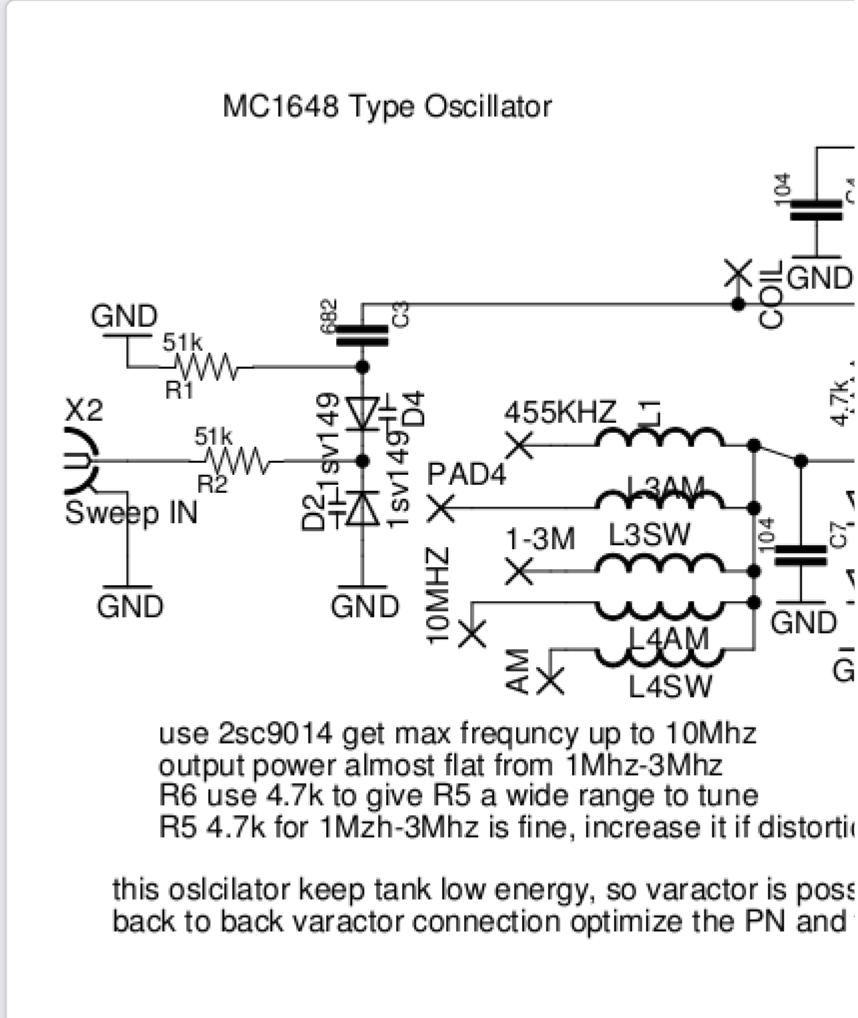
---

the VCO derived from VCO: Ultra Negtive 100kHz-100Mhz, use the Secondary ECL low tank energy VCO, which suitable for *Varactors.*

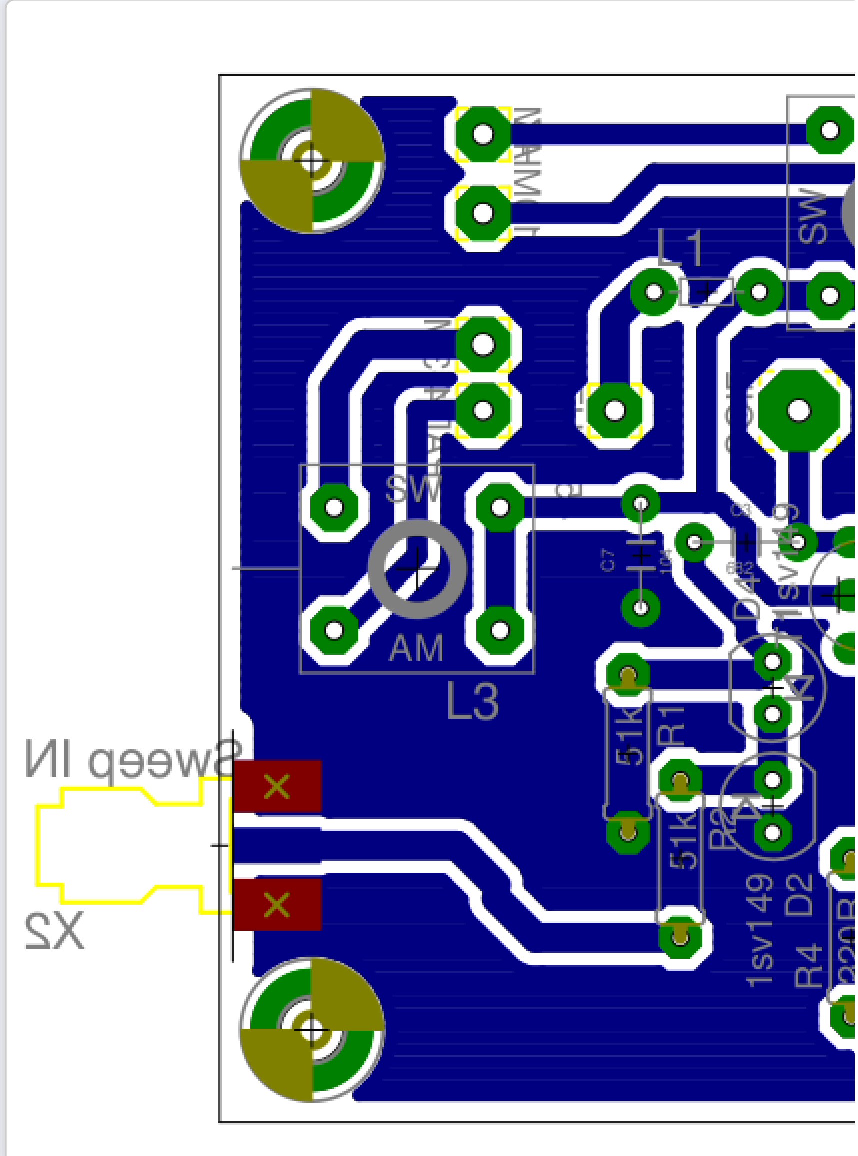
the total circuit is here:

Contact me

heyongli@gmail.com



Here is a reference layout for PCB.



@update 2013/10/6

1 year passed after i made this sweep signal generator, here is the problem:

1. no suitable case, just everything solder together.
2. VCO cover only 455khz to 12Mhz.
3. ramp generator : X sweep range is from 0 to several voltage, then need x10 probe to get perfect X sweep, actually the better way is use DC couple, -5V to +5V(-2.5 to 2.5 also good)
4. VCO sweep voltage from 0 to about 10V, which is not enough, at least need sweep from 0.5V to around 15V.
5. VCO sweep width is not calibration.

6. output level still not so flat, and output level is too low.
@2014/8/5

7. no frequency counter interface, which needed to read out frequency. @2014/8/5

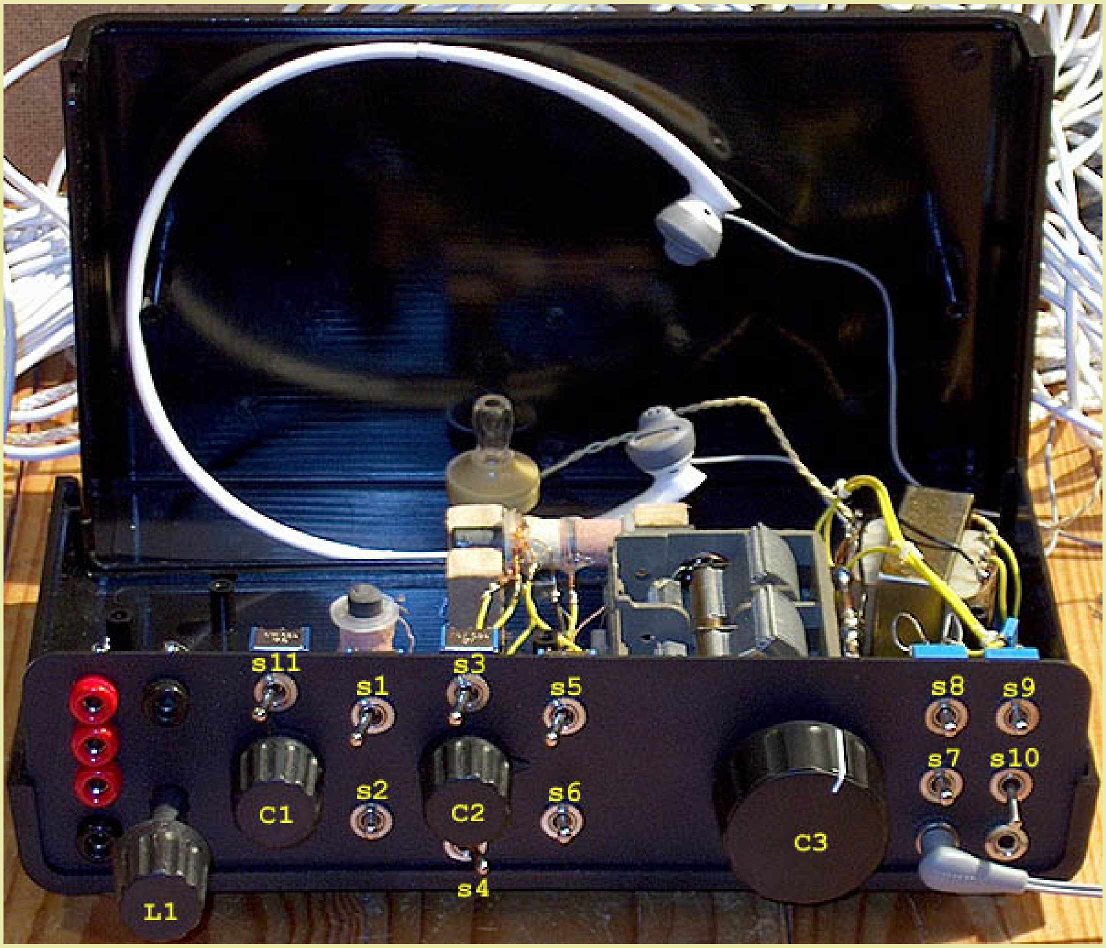
Comments

You do not have permission to add comments.

IMPROVED CRYSTAL RECEIVER FOR THE BTTF 2004

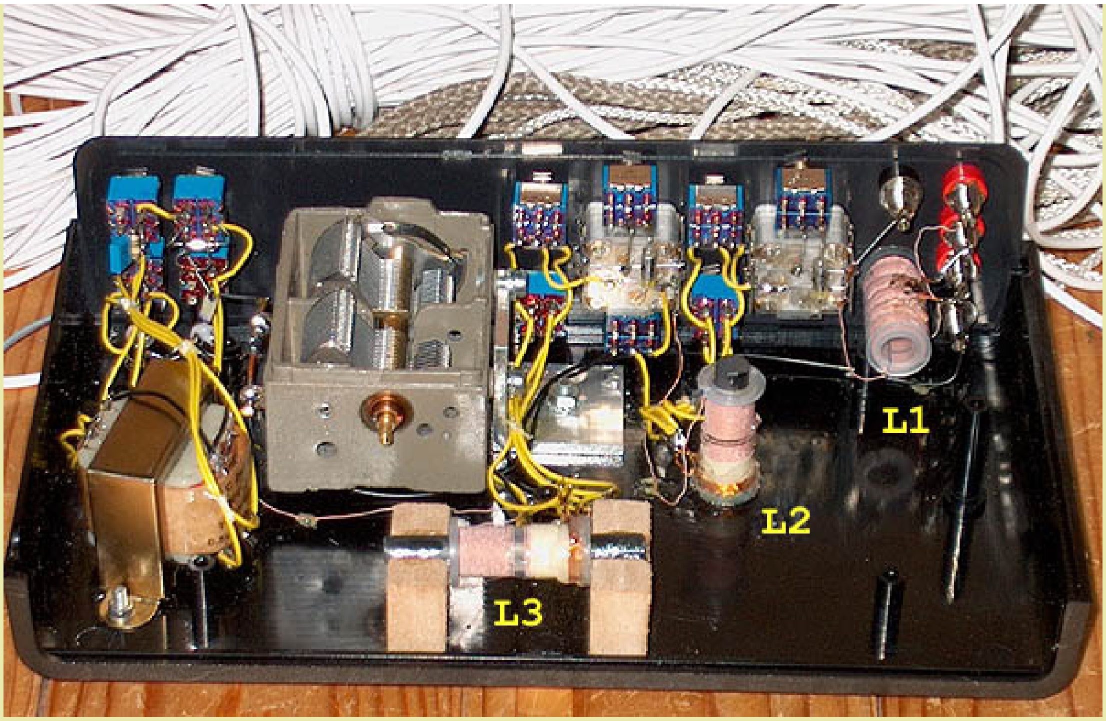
(2004)

KLIK HIER VOOR NEDERLANDSE VERSIE



The improved crystal receiver. Instead of the traditional crystal telephone, a Philips headphone model HS415 was used with the same or perhaps even better sensitivity and much better audio quality!

BTTF contest!
From December 25 to December 31, a contest is organized here in the Netherlands. The name is Back To The Future (BTTF). The challenge is to log as many medium wave stations as possible with a passive receiver.
Click HERE if you want to download the zipped *bttf2004log.doc* log of the stations I heard in December 2004 with this crystal receiver during that contest. There were 76 different medium wave stations identified, but some more unknown signals were heard.
Click HERE if you want to download the zipped *bttf2005log.doc* log of the stations I heard in December 2005 with this crystal receiver during that contest.
Click HERE if you want to download the zipped *bttf2006log.doc* log of the stations I heard in December 2006 with this crystal receiver during that contest.



Inside view

Improvements of the BTTF 2004 receiver compared to the BTTF 2003 receiver
This receiver also has the antenna tuner to improve the selectivity and sensitivity.
But it also has an extra L/C combination that can be switched (with S4) as a filter for extra selectivity or as a notch filter to suppress signals from strong broadcast stations. All coils do have litze wire now. The variable capacitor with reduction gear has a calibrated frequency scale, very useful to identify stations quickly.
It is also possible to select a germanium or a schottky diode (S8). Sometimes the germanium is better, sometimes the schottky diode. This experience was different from that with the BTTF 2003 receiver, in 2003 a germanium diode was always better....
The diode detector is not directly connected to a crystal telephone. Experiments showed that the sensitivity is better when an audio transformer is used and that the crystal telephone is connected to a tap of that audio transformer. It is also possible to use a low impedance headphone now. It can be connected to the secundary of the transformer.
During the contest, a Philips headphone model HS415 was used. Sensitivity and audio quality are better than that of the crystal telephone. Only one earpiece is connected, the impedance is 16 ohm and sensitivity 102 dB. Also very good is an Adastra driver unit model 952.207. But it is very heavy. For more information about the transformer used here and the very sensitive Adastra driver unit, see the nice site of Dick Kleijer about crystal receivers http://www.crystal-radio.eu/.

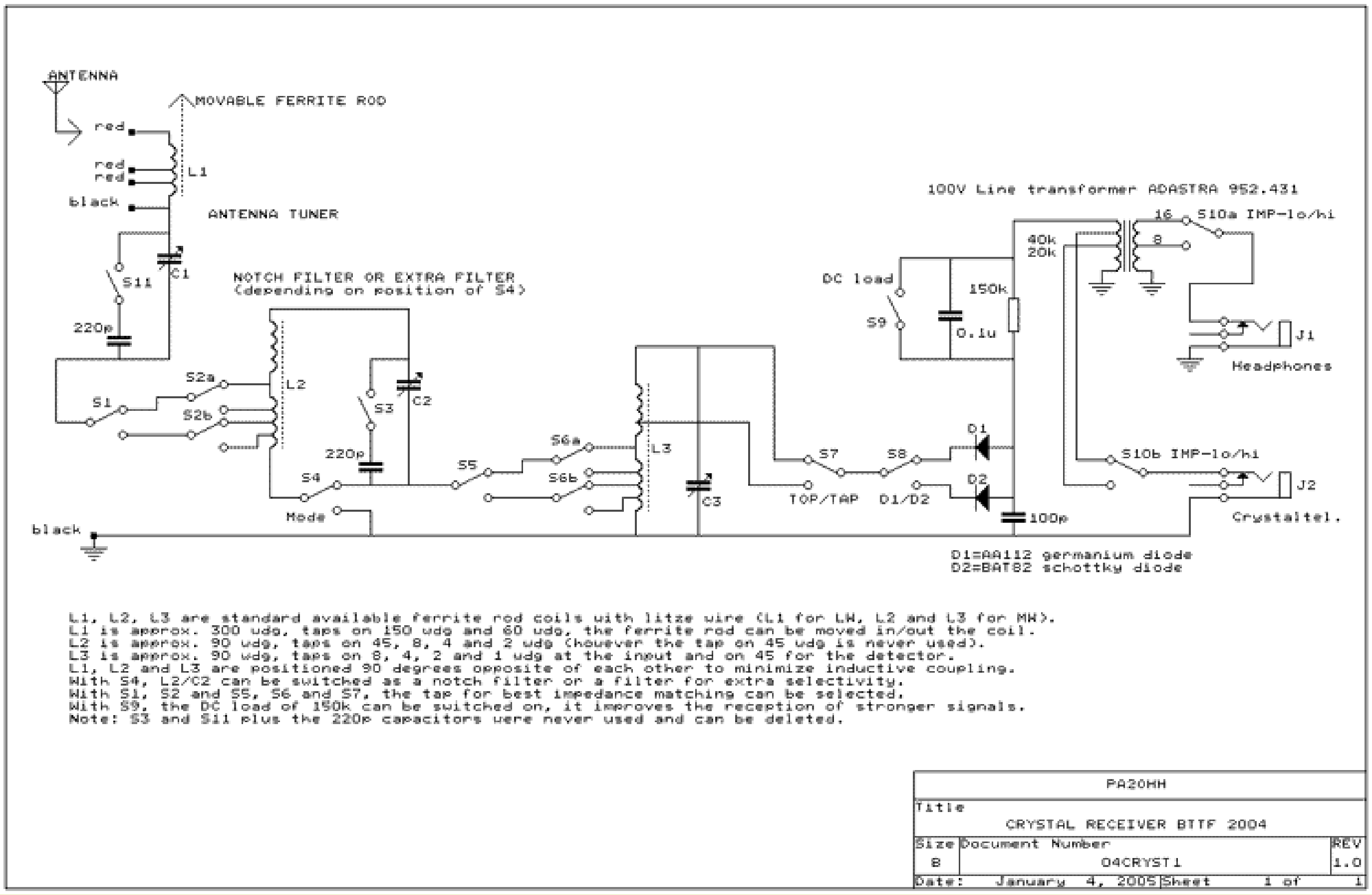
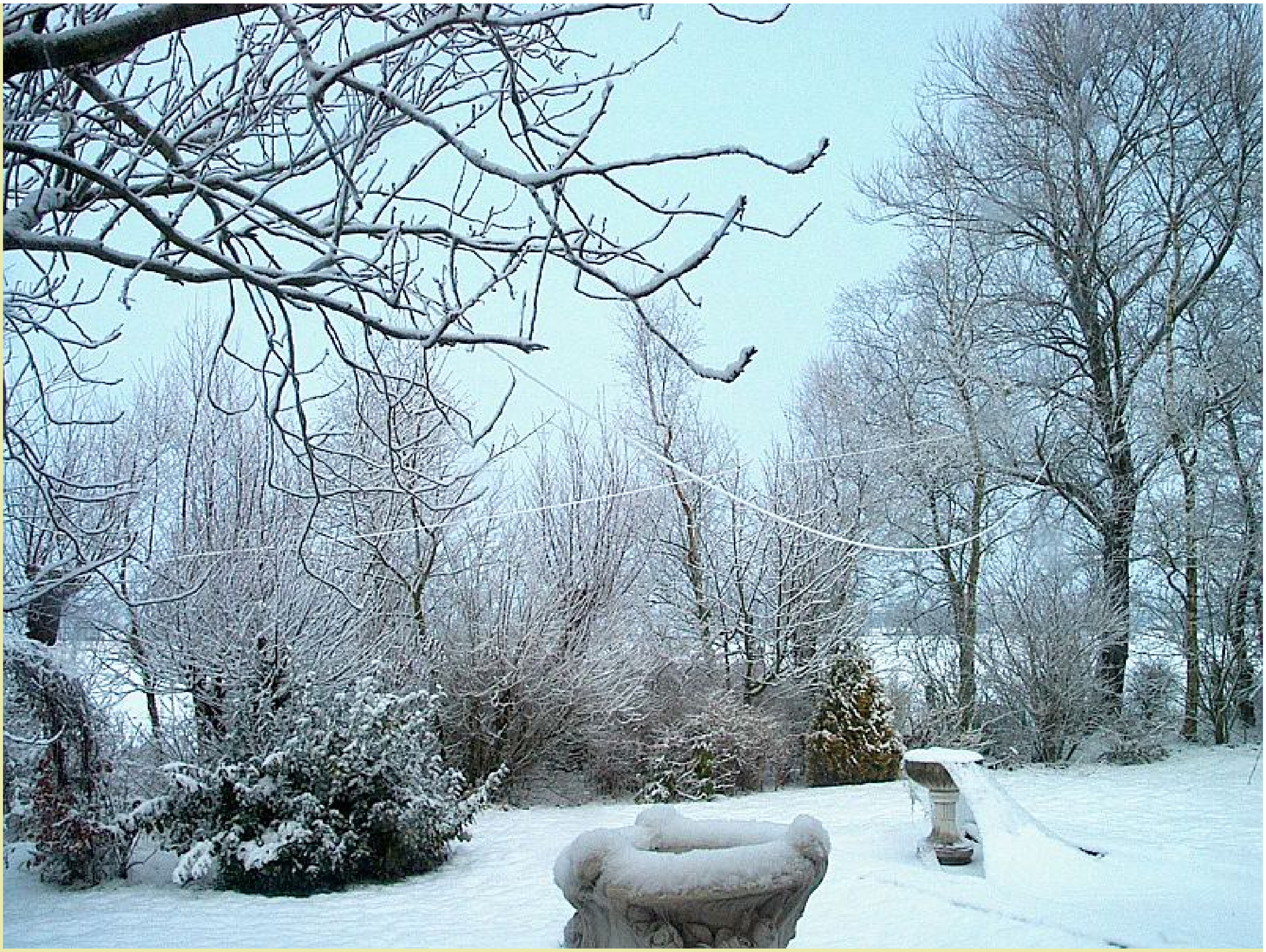


Diagram of the improved BTTF 2004 crystal receiver.
big diagram

Explanation
All coils are standard available coils for ferrite rods as used in broadcast receivers. L1 is a longwave reception coil, L2 and L3 are types for the medium wave. For the 8, 4, 2 and 1 winding taps, extra coils are wound with 0,3 mm copper wire.
L1 and C1 are the antenna tuner, tuning the antenna wire to resonance for maximum sensitivity and extra selectivity.
L2 and C2 are the extra filter. It can be used as a notch filter or as a filter for more selectivity (depending on the position of S4). I used it a lot as a notch filter (mostly the tap on 2 and 4 windings was used, sometimes the tap on 8 windings but the tap on 45 windings was never used).
L3 and C3 are the main selective tuning filter. Thanks to the very good variable capacitor with reduction gear and calibrated frequency scale, it was easy to identify the stations with use of a portable receiver with digital frequency read out. The diode detector can be connected to a tap (at 45 windings) or to the top of the coil. The tap is used above 1 MHz, the top connection below 1 MHz.
After the diode detector, the already mentioned transformer and crystal telephone or low impedance headphones can be found. As the transformer has almost no DC impedance, the 150k ohm resistor with the 0,1 uF capacitor are added so that the DC resistance is more or less similar to that of the AC impedance of the audio transformer. This is important for a distortion free reception. However, for weak signals the sensitivity is better when this DC load is switched off (S9).
Due to the loading of the detector and the antenna impedance, the Q factor of the coils will be reduced from more than 150 to somewhere between 50 and 100. Selectivity will be somewhere between 10 and 30 kHz.



Antenna during the BTTF 2005: to the tree right behind and then back to the left to a tree with a height of 2 meters

Antenna
The total length of the antenna is 50 meters. The first 30 meters run in the west-east direction, starting at a height of 3 meters to a tree at a height of 6 meters. The last 20 meters are running from this point to the south, ending at a height of 2 meters.

Selectivity
Measurements of the bandwidth:

Frequency	-3 dB	-6 dB	-20 dB
600 kHz	12 kHz	19 kHz	52 kHz
1000 kHz	15 kHz	23 kHz	99 kHz
1400 kHz	32 kHz	50 kHz	130 kHz

Sensitivity
A 10 mV rms source with a 25 ohm series resistance, 30% amplitude modulated gives an acceptable sound level. This a 1 microwatt RF signal at the input of the receiver. An RF signal of 100 mV rms gives a strong sound level in the headphone (100 microwatt RF signal).

Frequency scale
The scale that is used is the following table, calibrated in steps of 30 or 90 degrees:

0 = 450 kHz	-	-
90 = 500 kHz	-	-
180 = 531 kHz	-	-
270 = 585 kHz	-	-
360-0 = 645 kHz	-	-
90 = 750 kHz	120 = 810 kHz	150 = 850 kHz
180 = 880 kHz	210 = 920 kHz	240 = 975 kHz
270 = 1040 kHz	300 = 1110 kHz	330 = 1180 kHz
360-0 = 1250 kHz	30 = 1320 kHz	60 = 1410 kHz
90 = 1500 kHz	-	-
180 = 1800 kHz	-	-

BACK TO INDEX PA2OHH

An Improved Simple Crystal Set

(Updated 8 May 2003)

I've been working for a while to come up with a simple crystal set design that offers good performance, simple operation, and is made from readily available materials. All of the common hookups I tried worked OK during the day, but were often completely "crushed" by short-wave broadcast stations at night. (This can be a big problem here in the North-Eastern United States.) I believe I have a solution. I built a couple of reasonably successful sets like this using ferrite rods, but telling anybody how to reproduce the coils is a real problem. I'd like some of you to try this set, and tell me what you think.

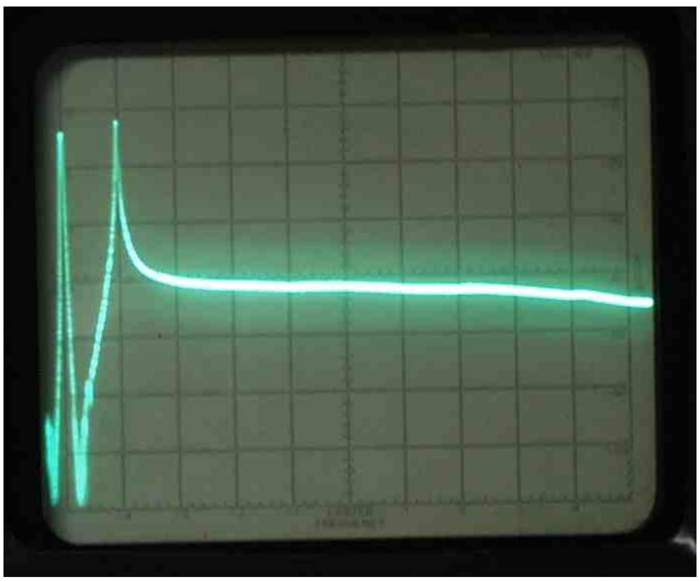
Desired Characteristics

- Easily reproducible by unsophisticated builders without tweaking
- Uses readily available components
- Good performance - "Gets DX"
- Easy operation
- Works well in the face of strong short-wave signals.

The Problem

Almost all single-tuned crystal sets have limited rejection on the high side of the frequency to which they are tuned. Furthermore, common crystal set antennas are often resonate (approximate 1/4 wavelength) in the 5-8 MHz region that contains several popular SW broadcast bands. If you're not in a metropolitan area, it's easy for the short-wave signals to be a lot stronger than the BCB stuff you're trying to hear.

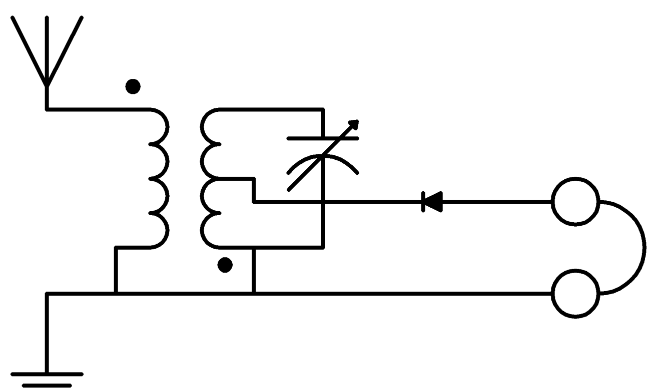
Consider the following screen photo: (Here's a block diagram of the TEST SETUP.)



Frequency response of a typical single-tuned crystal set using capacitive coupling (Tuggle circuit) tuned to 1000KHz. Horizontal scale is 1MHz per division, vertical is 10 dB per division. The peak at the left is the zero-frequency artifact of the spectrum analyzer. Set under test is tuned to 1MHz. The display shows the RF response of the tank circuit, which is center tapped and loaded by a 1N34 working into a 10K resistor. As you can see, the rejection in the crucial 5-10 MHz region is only about 30 dB. Here in New Jersey, strong short-wave signals crash right through. A classic double tuned circuit will do much better, but we're trying to keep things simple.

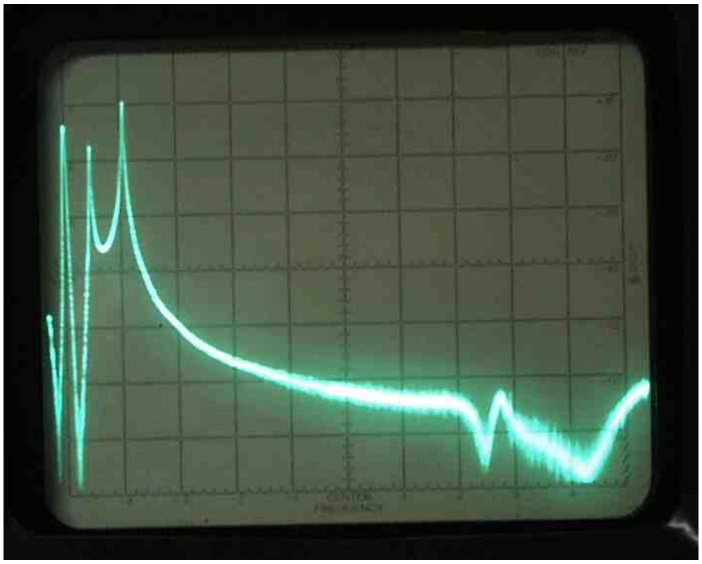
My solution

Schematically, there's nothing to it: A 365pF cap, a 1N34, a 2K-ohm (DC) headset, and the transformer.

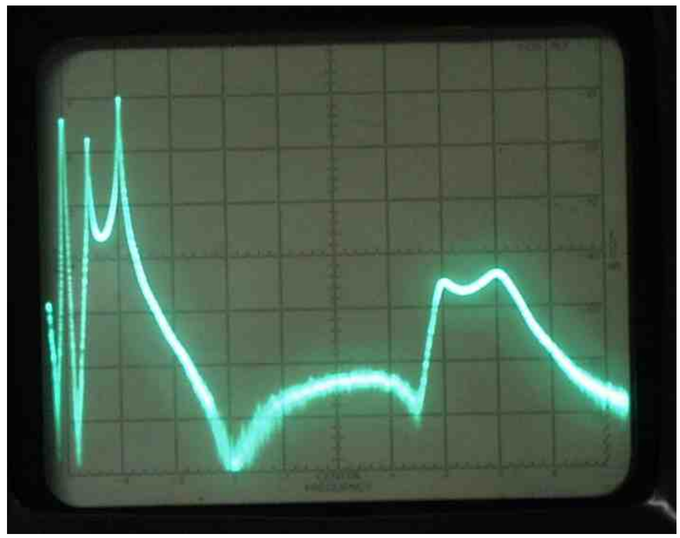


This is actually a double tuned circuit. The primary is self resonate at about 400 Khz, tightly coupled to the secondary, and tuned only by the

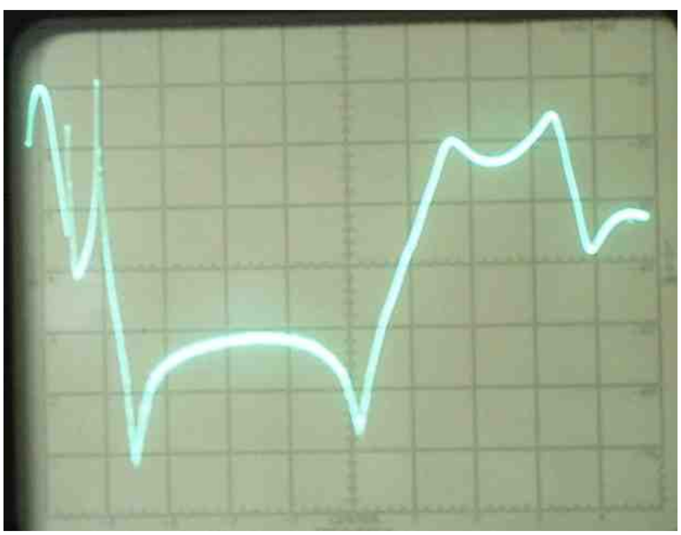
antenna capacity. The rejection of the primary and secondary add to give rejection of greater than 50 dB above 5 MHz. The set uses only one variable capacitor, and has no coupling adjustments or tap switches.



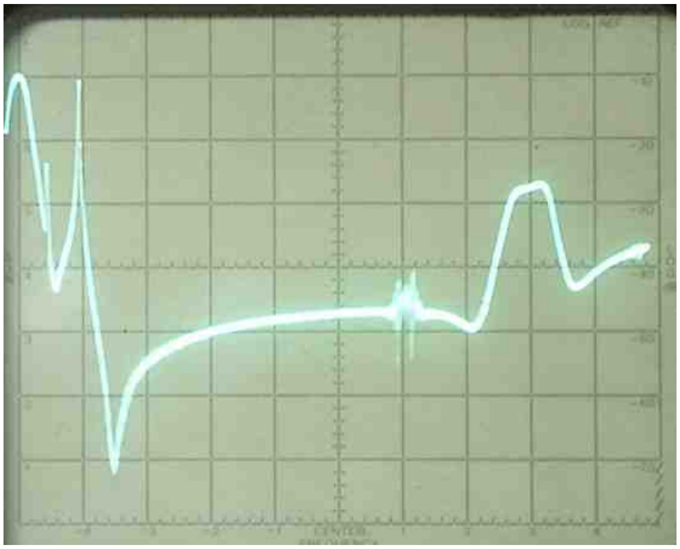
Because there is both inductive and capacitive coupling between the primary and secondary winding, phasing is important. Improper phasing will result in this sort of response. (In this case, right in the 40 - meter band!) If you hear shortwave, reverse the connections to the primary, or flip the coil over.

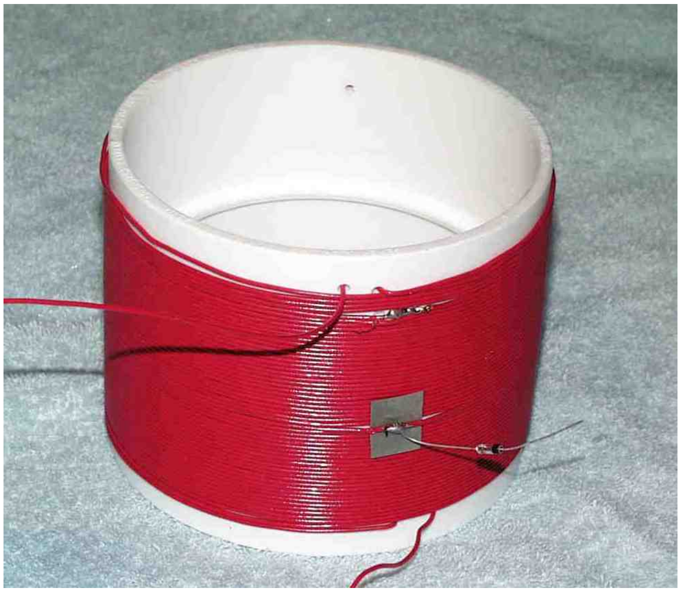


The above data were taken with the FET probe attached to the top of the secondary tank. I was assuming that the detector, on the center tap, was seeing a similar signal. (Years, ago my football coach warned what might happen if one were ASS-U-ME things.) The first night I tested the set, short-wave propagation must have been poor. Things seemed to work well, and I published this page. The following night, I had 40 and 49 meter signals all over the place. The frequency response, measured right at the detector, looked like this. (Left)



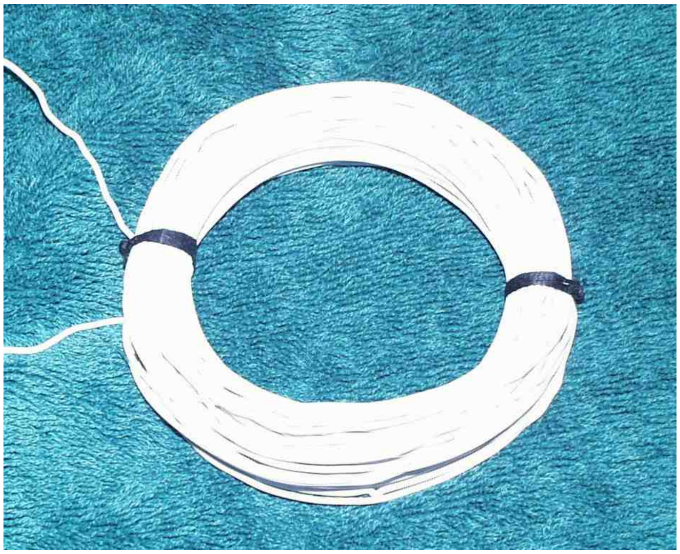
The simple expedient of applying a Faraday shield to the primary winding achieves reasonable shortwave rejection. The bump at 8MHz could be a problem if in wanders into one of the adjacent SW broadcast bands. The "grass" around the 6 MHz line is actual short-waves signals leaking into my test setup without the benefit of an antenna. (About 23:00 local time.)





Just as radio stations are defined by their antennas, radio receivers are defined by their coils. This one comes from Home Depot. The form is a 4" styrene pipe coupling. The wire started out as two-conductor #20 "thermostat wire." It's untinned solid copper. they make you buy 500 feet, so there's enough for 5 or 6 radios. The secondary is 55 turns tapped near the middle. (25 turns in this case.)

The primary is 75 turns of the same wire scramble wound around a 12-ounce beverage can, and tied to keep it neat.



The primary is wrapped in aluminum foil. The first couple of inches of foil are wrapped in electrical tape.

The end of the foil wrapping overlapps the beginning by about an inch. The tape prevents electrical contact between the two ends of the foil shield. If this insulation were not there, the foil would constitute a shorted turn in the coil, and destroy it's inductive characteristics.

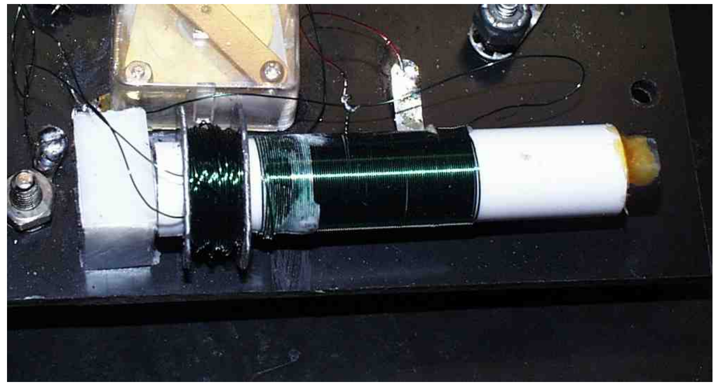
This Faraday shield keeps the electrostatic field inside, but allows the magnetic field to couple to the secondary.

The primary sits in the bottom (ground end) of the secondary. The objective is to maximize inductive coupling while limiting capacitive coupling. (I'll ad an updated picture, with the shielded primary, soon.)

I can't take credit for this design. This is how input coils for early tube radios were constructed when energy transfer was still important.

As I mentioned above, I started out making these transformers on ferrite rods. Details will vary with the rod material, wire gage, etc. The one at

the right is on a 3/8" rod salvaged from a transistor radio. The white plastic is hobby shop material, and cuts and glues nicely. The primary, in the bobbin, should be about 120% of the secondary turns count. The ferrite core provides tighter coupling than the air-core transformer, and the small size and physical arrangement of the windings control capacitive coupling, so the Faraday shield is not needed.

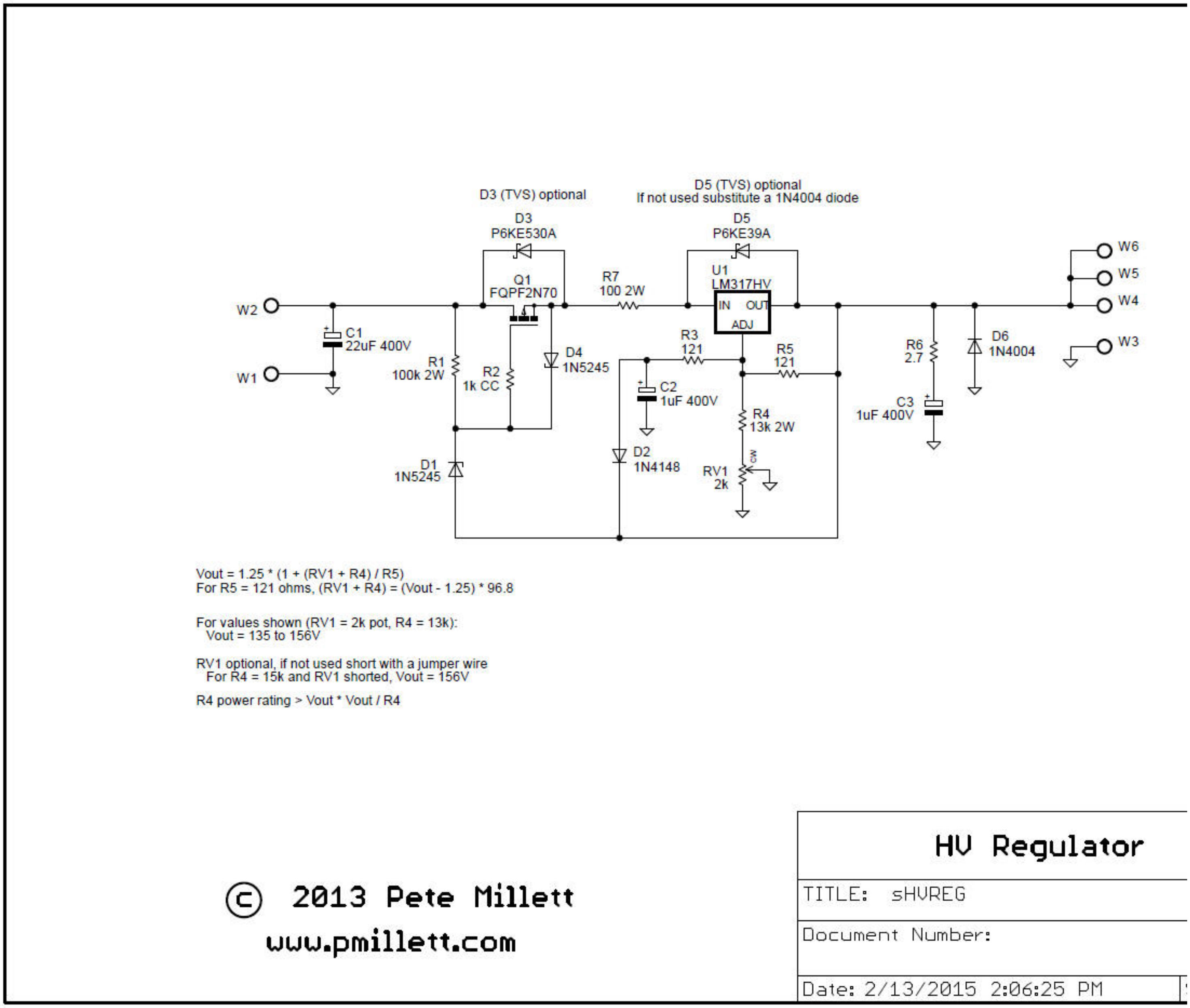


This circuit can make small sets worthwhile.

[DIY Audio Home]

High voltage regulator

This is an implementation of a "Maida-style" high voltage floating regulator. Here is the schematic (or download it as a PDF file):



This regulator is of the type originally shown in an application note by Michael Maida, then of National Semiconductor, in 1980. It showed a circuit capable of regulating high voltage using the LM317. The application note can be found on Texas Instruments' web site (TI bought National) here.

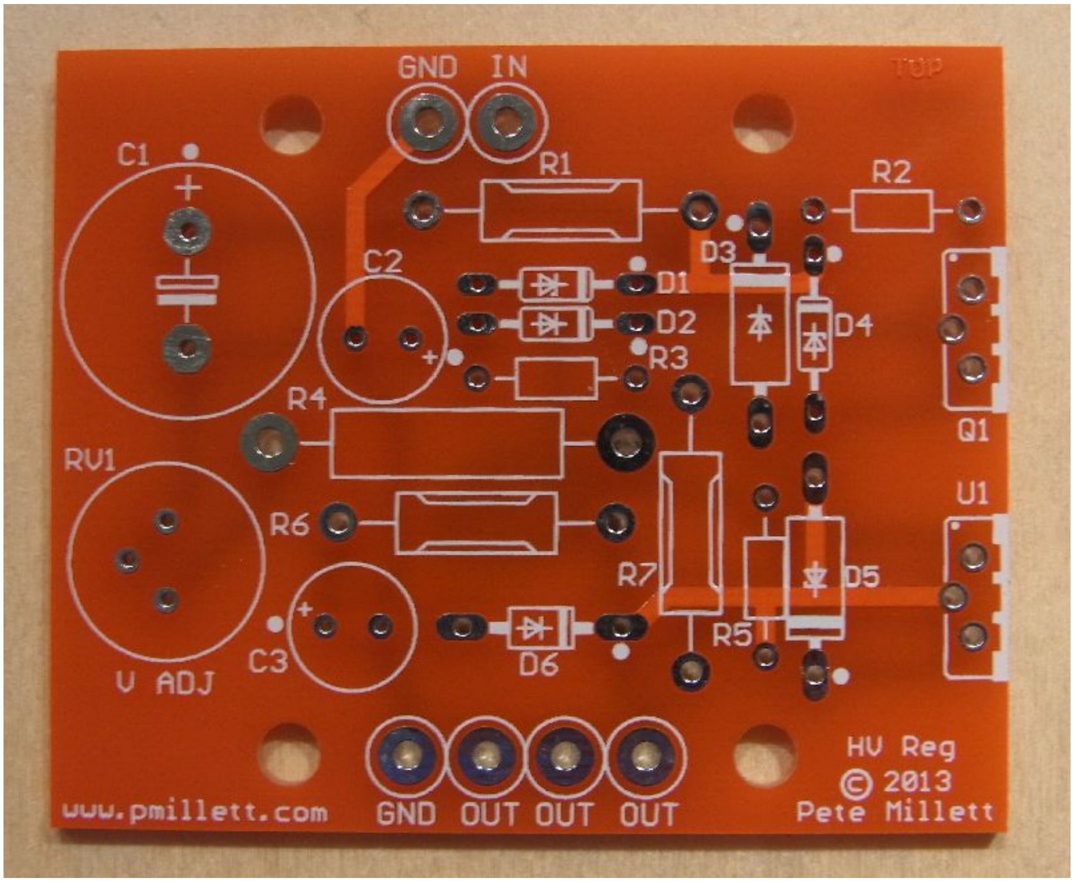
This version is similar, but uses a power MOSFET instead of a bipolar power transistor.

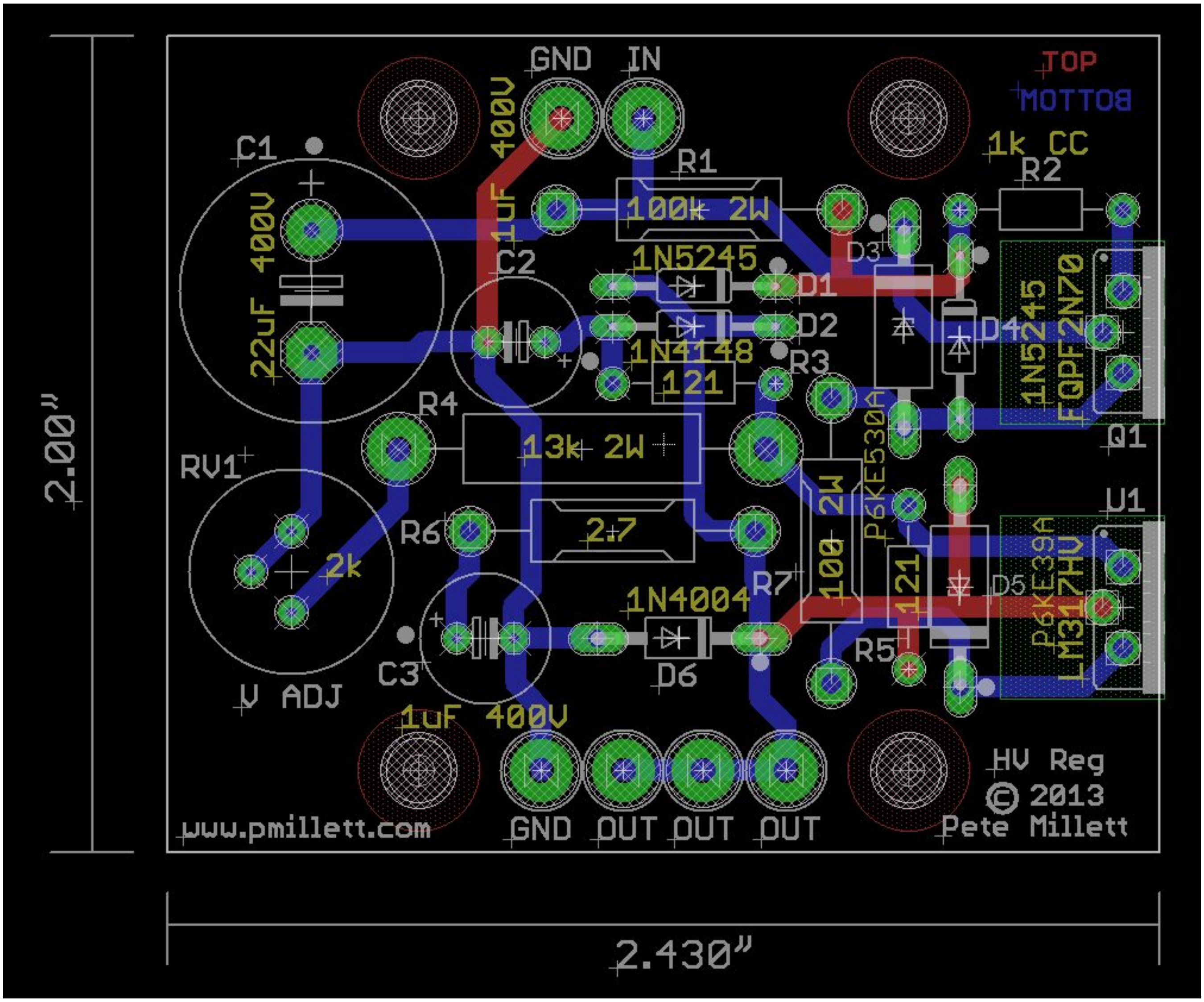
This type of regulator is typically used to provide a regulated voltage for the screen grid of a pentode, or B+ in a preamp. It can also be used to provide B+ in a power amp (though I personally think this is unnecessary in a power amp).

Since the regulator significant dissipates power - (Vin - Vout) * Iout watts, the power MOSFET needs a heatsink, possibly substantial in the case of large output current. I designed this PCB to fit the Landfall Systems heatsink, which allows you to get the heat up and out of the chassis. This heatsink can easily dissipate 10 watts or more, depending on how hot you want to allow it to be. Of course, you can also fabricate your own heatsink if you want.

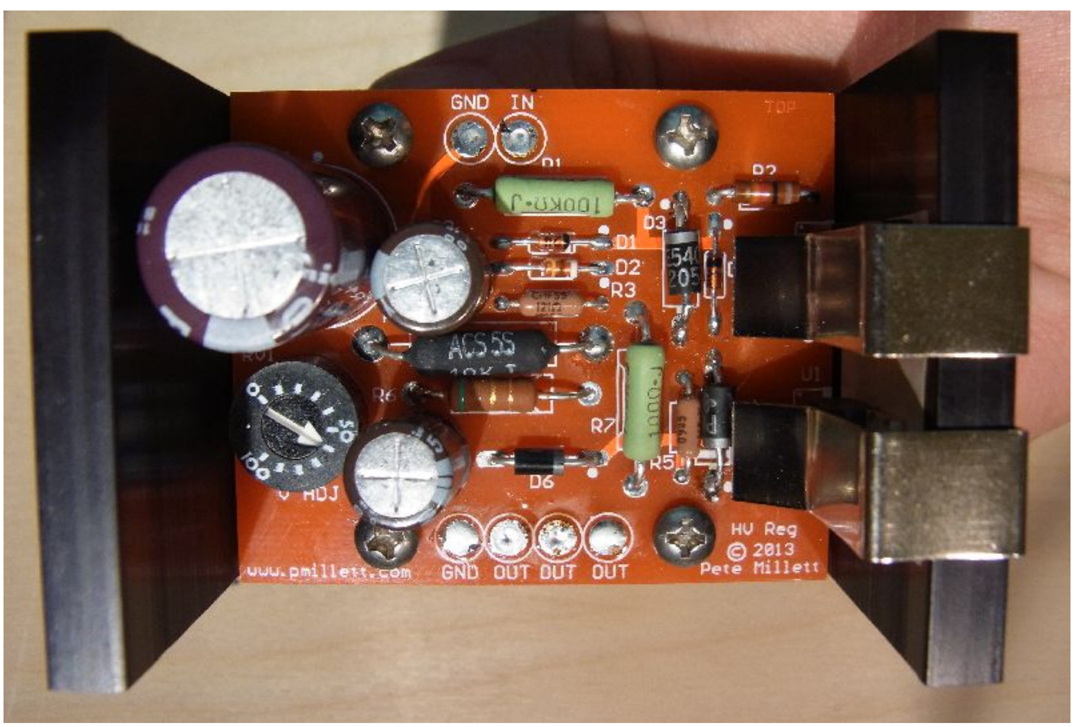
I also put the LM317 on the heatsink. This is not because it dissipates power - it only drops a small percentage of the voltage across the regulator - but to take advantage of its overtemperature shutdown feature. If the heatsink gets too hot, the LM317 will shut down.

Here is the PCB, available on eBay:


GND IN
TOP
C1
R1
R2
C2
D1
D2
D3
D4
R3
R4
Q1
RV1
R6
U1
R7
D5
R5
C3
D6
V ADJ
HV Reg
© 2013
Pete Millett
www.pmillett.com
GND OUT OUT OUT



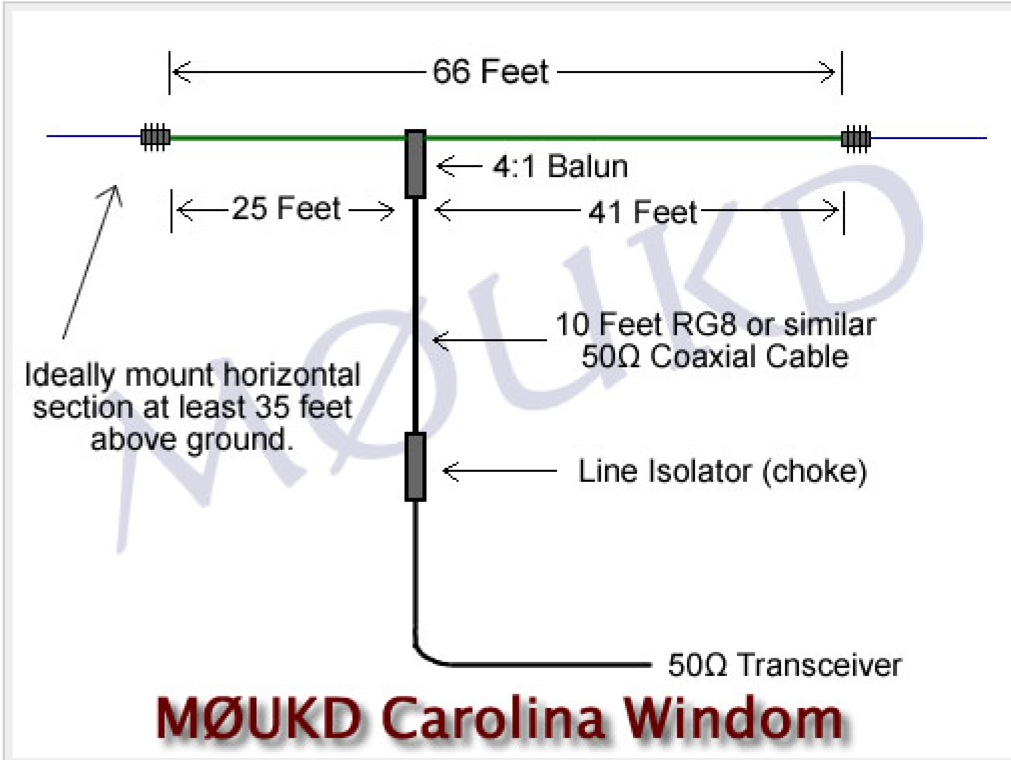
The assembled PCB installed onto the heatsink:

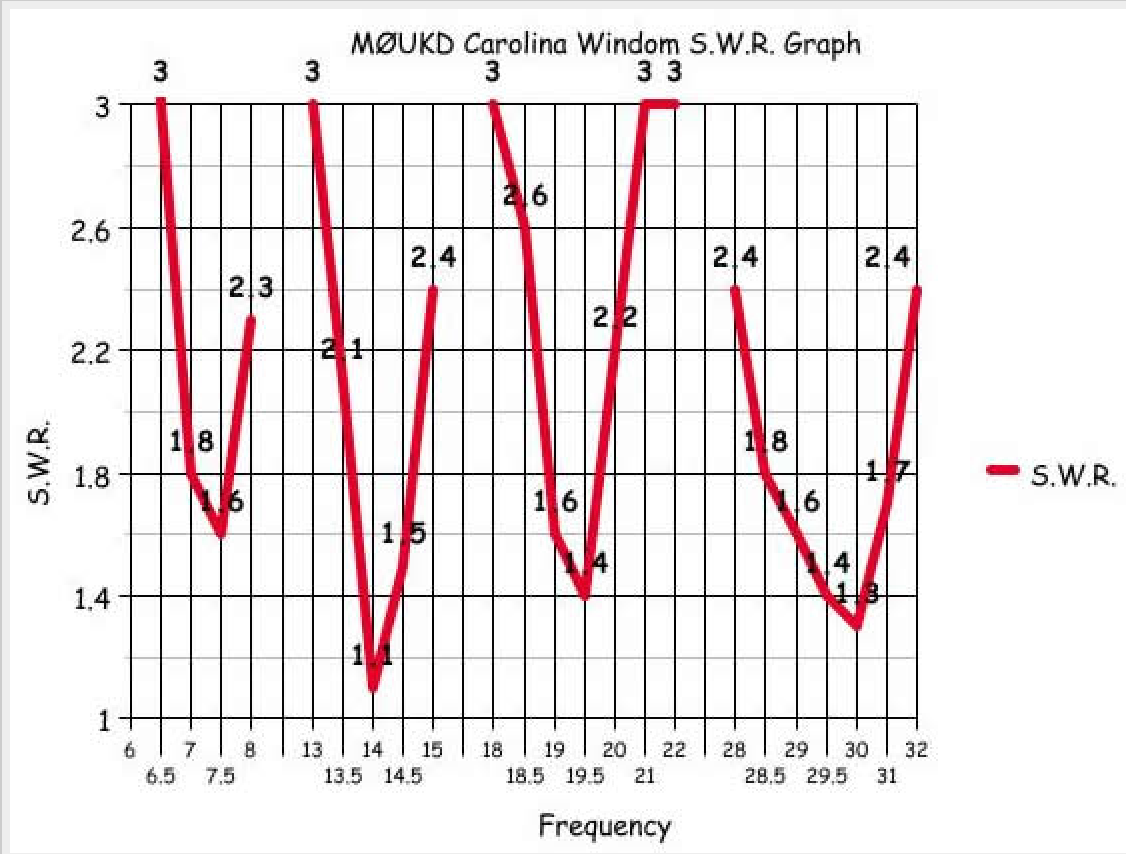


[Contact Landfall]about the heatsink. You can also get a prototype bard from them that lets you build your own circuit using this heatsink.

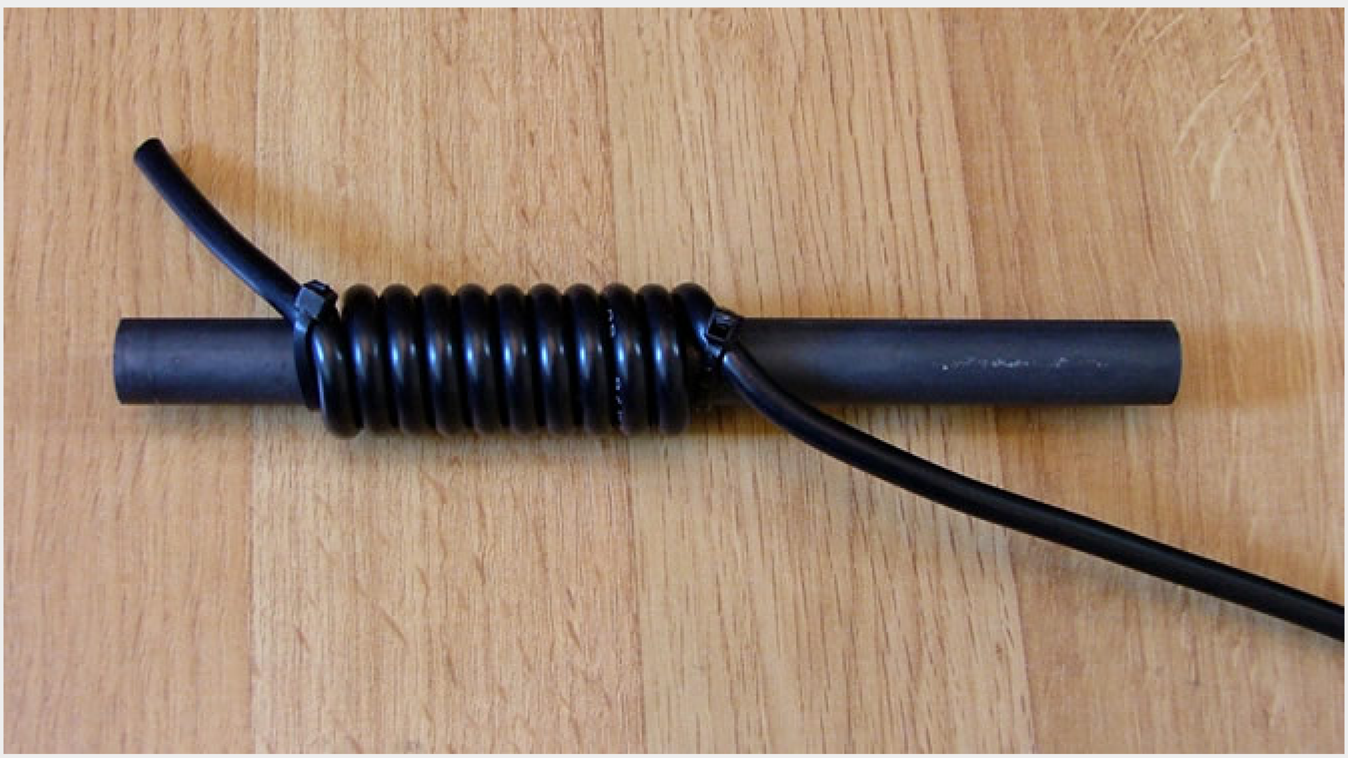
Note that you need to space the power devices such that the bottom of the plastic body is about 1/4' above the PCB, so that the heatsink and clips correctly mate with the heatsink.

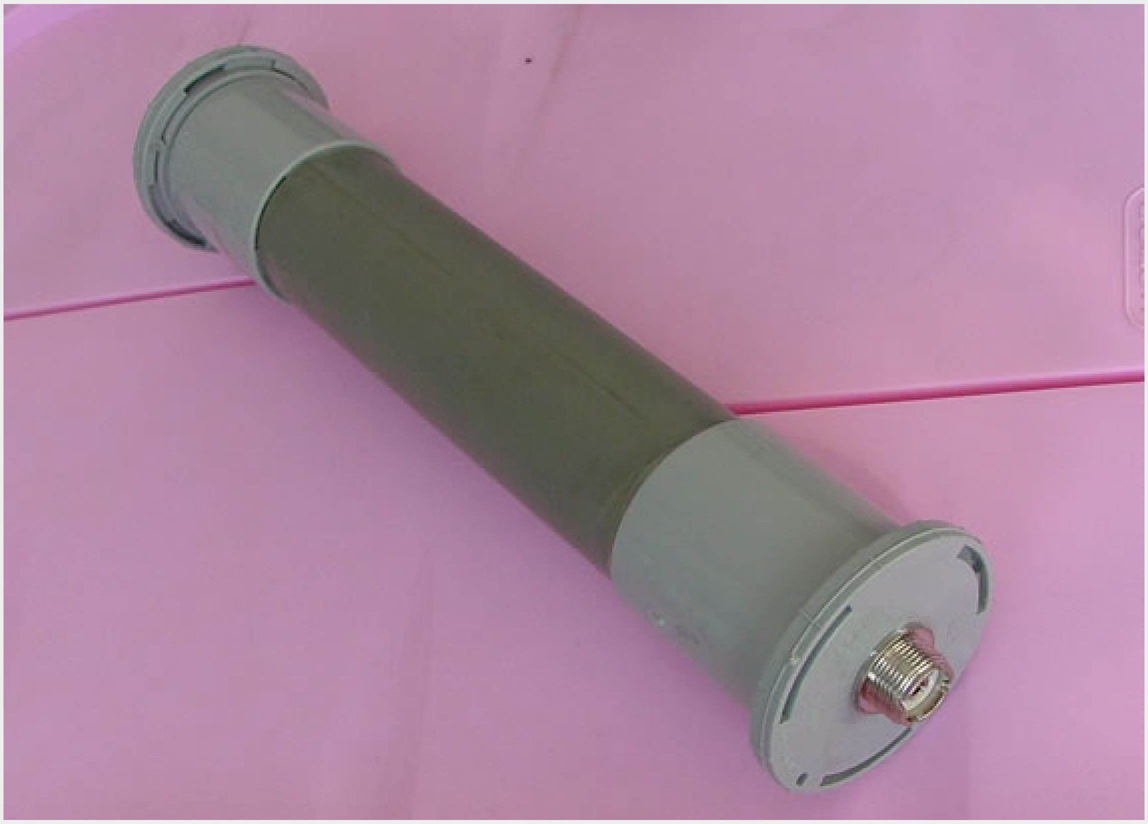
Homemade Carolina Windom antenna

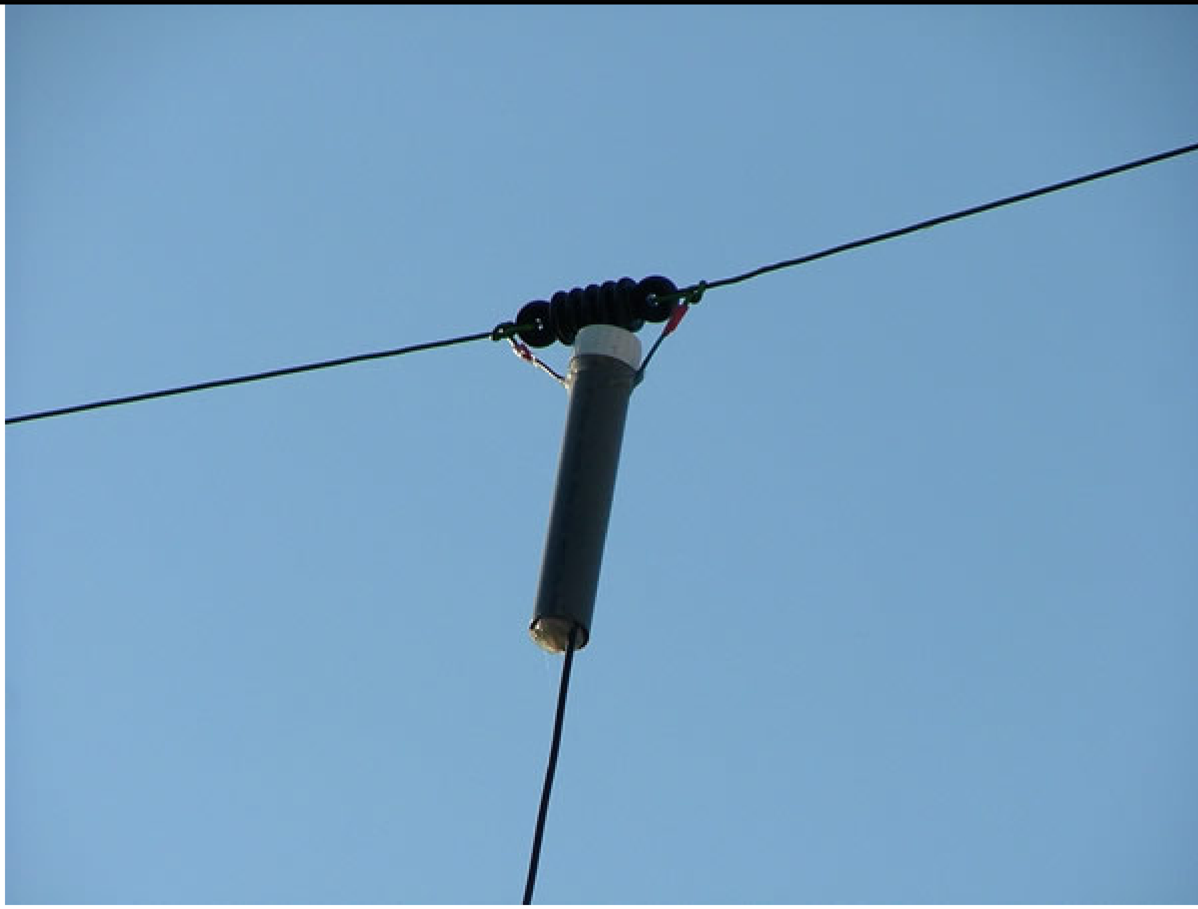


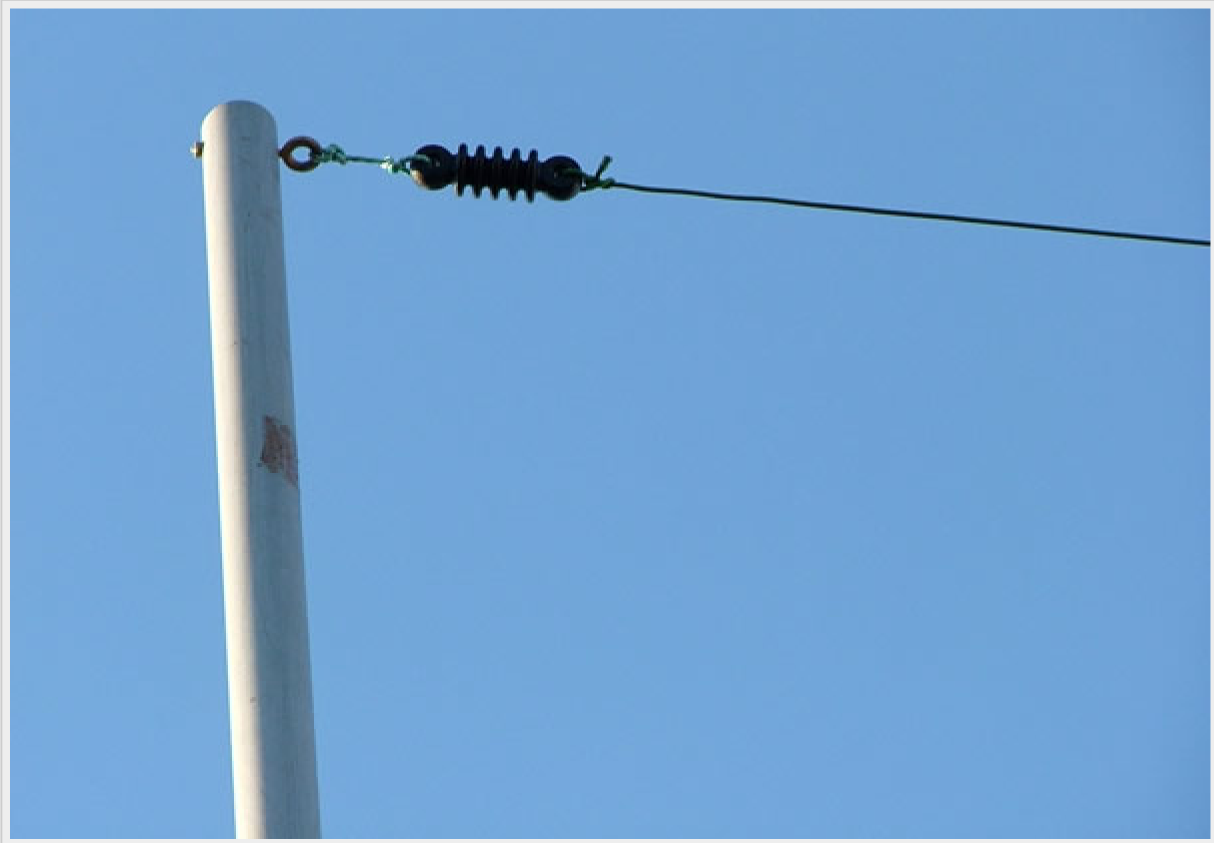

MØUKD Carolina Windom S.W.R. Graph
S.W.R.
Frequency
S.W.R.
3
2.6
2.2
1.8
1.4
1
6
6.5
7
7.5
8
13
13.5
14
14.5
15
18
18.5
19
19.5
20
21
22
28
28.5
29
29.5
30
31
32
3
1.8
1.6
2.3
3
2.1
1.1
1.5
2.4
3
2.6
1.6
1.4
2.2
3
3
2.4
1.8
1.6
1.4
1.3
1.7
2.4


4:1 Balun 1-30MHz - MØUKD









The International Amateur Radio Union

Since 1925, the Federation of National Amateur Radio Societies
Representing the Interests of Two-Way Amateur Radio Communication

ETHICS AND OPERATING PROCEDURES FOR THE RADIO AMATEUR

Edition 3
(June 2010)

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The website **http://www.ham-operating-ethics.org** houses all different versions of this document in more than 25 languages.

Translations:

If you are willing to help us with translating into another language, please contact one of the authors (on4un(at)uba.be or on4ww(at)uba.be). Someone else may already be working on a translation.

PowerPoint version:

A PowerPoint presentation version of this document is also available via the abovementioned link.

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The use of Commas and Full Stops: in this manual fractional parts are separated by a comma. Example: 3,51 MHz = 3.510 kHz, 1.000.000 = one million.

The Radio Amateur's Code

The Radio Amateur is

CONSIDERATE... He never knowingly operates in such a way as to lessen the pleasure of others.

LOYAL... He offers loyalty, encouragement and support to other amateurs, local clubs, the IARU Radio Society in his country, through which Amateur Radio in his country is represented nationally and internationally.

PROGRESSIVE... He keeps his station up to date. It is well-built and efficient. His ***operating practice*** is above reproach.

FRIENDLY... He operates slowly and patiently when requested; offers friendly advice and counsel to the beginner; kind assistance, cooperation and consideration for the interests of others. These are the marks of the amateur spirit.

BALANCED... Radio is a hobby, never interfering with duties owed to family, job, school or community.

PATRIOTIC... His station and skills are always ready for service to country and community.

-- adapted from the original Amateur's Code, written by Paul M. Segal, W9EEA, in 1928.

I. INTRODUCTION

I.1. WELCOME

Most radio amateurs or aspiring radio amateurs reading this manual are probably new to amateur radio. Up until recently, newcomers were thrown on the bands with very little, if any, help, without clear instructions or teaching on *how* to behave on the air. Can you imagine being released on the roads, in heavy traffic, without anyone having told you how to drive a car or how to behave on the road? This idea by itself seems frightening to most of us. Appearing on the ham bands without being prepared for this wonderful experience could be equally intimidating, to say the least. Don't panic though, everybody some day drove a car for the first time, and every ham was a new ham at first.

Welcome to the world of ham radio, welcome to our bands. This document will help you to better enjoy this wonderful hobby, right from the start. Don't forget, ham radio is a hobby, and a hobby by definition is something you enjoy!

The reader should not let himself be deterred by the many *rules* in this manual, thinking that these would lessen the pleasure and satisfaction of making radio

contacts. These rules are easy to understand and will rapidly become an automatic code of conduct for every ham *of good will*.
This manual is divided in three parts:

I. Introduction
Why this manual?

II. General Operating
This section applies to all radio amateurs, whatever kind of operating they do (rag chewing, DX chasing, contesting etc.).

III. Advanced Operating
This section covers subjects mainly linked to DXing: making QSOs in pile-ups, using the DX Cluster, DX nets, being the DX operator in a *rare* country, conflict situations etc.

I. 2. AMATEUR RADIO CODE OF CONDUCT

I. 2.1. Basic principles

Basic principles that should govern our **code of conduct** on the ham bands are:

- **Social feeling, feeling of brotherhood, brotherly spirit:** large numbers of us are all playing radio on the same airwaves (our playing field). We are never alone. All other hams are our colleagues, our brothers and sisters, our friends. Act accordingly. Always be considerate.
- **Tolerance**: not all hams necessarily share your opinions, and your opinions may also not be the *best* ones. Understand there are other people with different opinions on a given subject. Be tolerant. This world is not for you exclusively.
- **Politeness**: **never** use rude language or abusive words on the bands. Such behaviour says nothing about the person it is addressed to, but a lot about the person behaving that way. Keep yourself under control at all times.
- **Comprehension**: please understand that not everyone is as smart, as professional or as much an expert as you. If you want to do something about it, **act positively** (how can I help, how can I correct, how can I teach) rather than negatively (cursing, insulting etc.).

I.2.2. The danger of conflicts

Only one playing field, the ether: all hams want to play their game or want to exercise their sport, but it all has to be done on a single playing field: our amateur bands. Hundreds of thousands of players on a single playing field will sometimes lead to conflicts.

An example: All of a sudden you hear someone calling CQ or talking to someone else on *your* frequency (the frequency you've been using for a while). How is that possible? You were here for more than half an hour on a perfectly clear frequency! Yes, it IS possible; maybe that other station thinks as well that you have intruded on HIS frequency. Maybe the *skip* or propagation has changed.

I.2.3. How to avoid conflicts?

- By explaining to all players what the rules are, and by motivating them to apply these rules. Most of the actual conflicts are caused by **ignorance**: many hams don't know the rules well enough.
- In addition, many conflicts are handled in a poor way, once again through ignorance.
- This manual is intended to do something about this lack of knowledge, mainly aiming at avoiding conflicts of all sorts.

I.2.4. The moral authority

- In most countries the authorities do not care in detail how hams behave on their bands, providing that they operate according to the rules laid down by the authorities.
- The radio amateur community is said to be largely **self policing**, this means **self discipline** has to be the basis of our conduct. It does NOT mean though that the ham community has its **own police services**!

I.2.5. The code of conduct

What do we mean by ***code of conduct***? The code of conduct is a set of rules based on principles of **ethics**, as well as **operational considerations**.

- **Ethics:** determine our attitude, our general behaviour as radio amateurs. Ethics have to do with morals. Ethics are the principles of morals.

    Example: ethics tell us never willingly to interfere with transmissions from other stations. This is a moral rule. Not living by it is immoral, as is cheating in contests.
- **Practical rules**: to manage all aspects of our behaviour there is more than just ethics, there are also a number of rules based on **operational considerations** and on radio amateur **practice and habits**. To avoid conflicts we also need practical rules to guide our behaviour on the amateur bands, as making contacts on the bands is one of our principal activities. We are talking very **practical rules** and **guidelines**, governing aspects that are not related to ethics. Most operating procedures (how to make a QSO, how to call, where to operate, what QRZ means, how to use the Q code etc.) form part of it. Respect for the procedures guarantees optimal performance and effectiveness in our QSOs and will be a key in avoiding conflicts. These procedures came about as a result of daily practice over many years and as a result of ongoing technological developments.

I.2.6. This manual

- The manual is entirely dedicated to the code of conduct of radio amateurs. For the greatest part this code of conduct consists of operational procedures, topped off with the moral principles which are the foundation for our general behaviour as explained above.
- Knowledge of the **amateur code of conduct** is as important for hams as the knowledge of the national rules and regulations and the basics of electricity, electronics, antennas, propagation, safety etc.
- This manual aims to make all hams familiar with this code of conduct on the bands, whether they are old timers or newcomers or candidate hams.

- This has never been done so far in such great detail, and the detailed knowledge of this code of conduct has so far not been included in either the study or the exam material for candidate hams. This appears to be one of the reasons why, unfortunately, we hear so many shortcomings and infringements of this code of conduct on our bands.
- Teaching newcomers and testing their knowledge during the radio amateur exams will hopefully make it less necessary to correct situations on the air, and will make our bands a more attractive place for all of us where cursing, jamming and shouting will soon be only a bad memory.
- Hams make errors regarding these operating procedures mainly because they have never been taught how to behave correctly. They have hardly been trained on this subject. We should not blame them, we should train them!
- This manual covers operating procedures regarding the most used transmission modes (SSB, CW, RTTY and PSK).

II. GENERAL OPERATING

II.1. HAM LANGUAGE

- A ***ham*** is a radio amateur.
- As hams we address one another exclusively with their first name (or nickname), never with *mister*, *miss* nor *misses* or with a family name. This is also true for written communication between hams.
- The ham etiquette says we greet one another in our writings using '*73*' (not *best 73* nor *many 73*), and not *sincerely* or other similar formal expressions.
- If you used to be a CB operator, erase the CB language from your memory, and learn the amateur radio idioms (jargon, slang) instead. As a member of the amateur radio community you are expected to know the typical amateur radio expressions and idioms, which will help you to become fully accepted by the ham community.
- During your on-the-air contacts, use the **Q code** (attachment 2) **correctly**. Avoid overkill by using the Q code all the time in phone. You can also use standard expressions that everybody understands. Some Q codes have however become standard expressions even in phone, e.g.:

The QRG	the frequency
QRM	interference
QRN	interference from atmospherics (static crashes)
A QRP	a child
Going QRT	leave the air, stop transmitting
Being QRV	being ready, being available
QRX	just a moment, stand by
QRZ	who called me?
QSB	fading
QSL (card)	the card which confirms a contact
QSL	I confirm
A QSO	a contact
QSY	change frequency
QTH	the place where your station is located (city, village)

- As well as the small number of Q codes which are commonly used on phone, there are some other *short* expressions that stem from CW (see § II.9.28) and that have become commonplace on phone, such as 73, 88, OM (*old man*), YL (*young lady*), etc.
- Use the one and only **international spelling alphabet** (attachment 1) correctly. Avoid *fantasies* which may sound funny or amusing in your own language, but which won't make your correspondent understand what you are saying… Do not use different spelling words in one and the same sentence. Example: '*CQ from ON9UN, oscar november nine uniform november, ocean nancy nine united nations…*'
- The most widely used language in amateur radio is undoubtedly English. If you want to contact stations all over the world it is likely that a majority of your contacts will be made in English language. It goes without saying though that two hams, both speaking language different from English can of course converse in that language.
- Making contacts in Morse code (CW) is always possible without speaking a single word in the language of your QSO partner.
- It is clear that the hobby can be an excellent tool for learning and practicing languages. You will always find someone on the bands that will be happy in helping you with a new language.

II.2. LISTEN

- A good radio amateur starts by listening a lot.
- You can learn a lot by listening but be careful, not all you hear on the bands are *good examples*. You will certainly witness a lot of incorrect operational procedures.
- If you are active on the bands, be a **good example** on the air and apply the guidelines as explained in this document.

II.3. USE YOUR CALLSIGN CORRECTLY

- Instead of ***callsign*** or ***call letters***, hams usually employ the short form ***call***.
- Use only your **complete** call to identify yourself. Don't start your transmission by identifying yourself or your correspondent by your or his first name (e.g. saying: *hello Mike, this is Louis…*).
- Identify yourself with your FULL callsign, not just the suffix! It is illegal to just use the suffix.
- Identify yourself *frequently.*

II.4. ALWAYS BE A GENTLEMAN

- Never use abusive terms, **stay polite, courteous and gentle, under all circumstances.**
- George Bernard Shaw once wrote: *There is no accomplishment so easy to acquire as politeness and none more profitable*.

II.5. ON THE REPEATER

- Repeaters serve in the first place to extend the operating range of portable and mobile stations on VHF/UHF.
- Use simplex wherever possible. Using repeaters to make contacts between two fixed stations should be an exception.
- If you want to talk via the repeater while it is already in use, wait for a pause between transmissions to announce your call.
- Only use the term 'break' or even better 'break break break' in an emergency or life-threatening situation. Better is to say 'break break break with emergency traffic'.
- Stations using the repeater should pause until its carrier drops out or a beep appears, to avoid inadvertent *doubling* (simultaneous transmission) and to allow time for new stations to identify. Pausing usually also allows the timer to reset, avoiding a *time-out.*
- Do not monopolize the repeater. Repeaters are there not only for you and your friends. Be conscious that others may want to use the repeater as well; be obliging.
- Keep your contacts through a repeater short and *to the point*.
- Repeaters should not serve to inform the XYL that you are on your way home and that lunch can be served... Contacts through amateur radio concern primarily the technique of radio communications.
- Don't break into a contact unless you have something significant to add. Interrupting is no more polite on the air than it is in person.
- Interrupting a conversation without identification is not correct and in principle it constitutes illegal interference.
- If you frequently use a particular repeater consider supporting those that keep that repeater on the air.

II.6. HOW DO YOU MAKE A QSO?

- A **QSO** is a contact by radio between two or more hams.
- You can make a general call (**CQ**), you can answer someone's CQ or call someone who has just finished a contact with another station. More on this follows...
- Which call comes first in your conversation? Correct is: 'W1ZZZ from G3ZZZ' (you are G3ZZZ, and W1ZZZ is the person you address). So, first give the call of the person you speak to, followed by your own call.
- How often should you identify? In most countries the rule is: *at the beginning and at the end of each transmission, with a minimum of at least once every 5 minutes*. A series of short *overs* is usually considered to be single transmission. In a contest it is not strictly necessary, from the viewpoint of the rule maker, to identify at each QSO. This 5 minute rule has come about as a requirement from the monitoring stations to be able to easily identify stations. From an **operational** point of view however, the only good procedure is to identify **at each QSO** (see also framed text on page 62).
- A *pause* or a *blank*: when your correspondent switches the transmission over to you, it is a good habit to wait a second before starting your transmission, in

order to check whether someone may want to join you, or use the frequency.
- Short or long transmissions? Preferably make short rather than long transmissions, this makes it much easier for your correspondent if he wants to comment on something you said.

II.7. WHAT DO YOU TALK ABOUT ON THE AMATEUR BANDS?

The subjects of our communications should always be related to the amateur radio hobby. Ham radio is a hobby regarding the **technique of radio communications** *in the broad sense of the term*. We should not use amateur radio to pass along the shopping list for tonight's dinner...

Some subjects which are a **no no** in amateur radio conversations on the air are:
- religion;
- politics;
- business (you can talk about your profession, but you cannot advertise for your business);
- derogatory remarks directed at any group (ethnic, religious, racial, sexual etc.).
- bathroom humor: if you wouldn't tell the joke to your ten year old child, don't tell it on the radio;
- any subject that has no relation whatsoever with the ham radio hobby.

II.8. MAKING CONTACTS ON PHONE

II.8.1. How do you call CQ?

Sometimes before transmitting it is necessary to tune (adjust) the transmitter (or antenna tuner). Tuning should in the first instance be done on a dummy load. If necessary, fine tuning can be done on a clear frequency with reduced power, after having asked if the frequency is in use.
- What should you do first of all?
  - Check which band you want to use for the distance and the direction you want to cover. MUF charts are published on many websites, and can help in predicting HF propagation.
  - Check which portion of the band you should use for phone contacts. Always have a copy of the IARU Band Plan available on your operating desk.
  - Remember, SSB transmissions below 10 MHz are done on LSB, above 10 MHz on USB.
  - Also, when you transmit on USB on a given nominal (suppressed carrier) frequency, your transmission on SSB will spread at least 3 kHz above that frequency. On LSB it is the inverse, your signal will spread at least 3 kHz below the frequency indicated on your rig. This means: never transmit on LSB below 1.843 kHz (1.840 is the lower limit of the sideband section); never transmit on LSB below 3.603 kHz, or on USB never above 14.347 kHz, etc.
  - And then?
  - Now you are ready to start listening for a while on the band or frequency you intend to use...
  - If the frequency seems to be clear to you, ask if it is in use ('anyone using this frequency?' or 'is this frequency in use?'). Some operators ask 'is this

frequency clear?', but asking this way may lead to confusion. It does not mean that, if a frequency is 'clear' for one particular station, it really is a clear frequency. So, let's find out if other stations are already using the frequency by asking: 'anyone using this frequency?' or 'is this frequency in use?'.
- If you have already listened for a while on an apparently clear frequency, why do you in addition have to ask if the frequency is in use? Because one station, part of a QSO, who is located in the skip zone vs. your location, could be transmitting on the frequency. This means that you cannot hear him (and he won't hear you) because he is too far for propagation via ground wave and too close for propagation via ionospheric reflection. On the higher HF bands this usually means stations located a few hundred kilometers from you. If you ask if the frequency is in use, his correspondent may hear you and confirm. If you start transmitting without asking, chances are you will be causing QRM to at least one of the stations on frequency.
- If the frequency is occupied, the user will most likely answer 'yes' or more politely 'yes, thank you for asking'. In this case you have to look for another frequency to call CQ.
- And if nobody replies?
- Ask again: 'is this frequency in use?'
- And if still no one replies?

- Call CQ: 'CQ from G3ZZZ, G3ZZZ calling CQ, golf three zulu zulu zulu calling CQ and listening'. At the end you may say '...calling CQ and standing by', instead of '...and listening'. One could also say: '...and standing by for any call'.
- Always speak clearly and distinctly, and pronounce all words correctly.
- Give your call 2 to maximum 4 times during a CQ.
- Use the international spelling alphabet (for spelling out your callsign) once or twice during your CQ.
- It's better to use several consecutive short CQs rather than one long CQ.
- Do not end a CQ with 'over', as in this example: 'CQ CQ G3ZZZ golf three zulu zulu zulu calling CQ and standing by. Over'. 'Over' means 'over to you'. At the end of a CQ you cannot turn it over to anyone as you are not yet in contact!
- Never end a CQ by saying 'QRZ'. 'QRZ' means 'who was calling me?'. It is obvious that nobody WAS calling you before you started your CQ! A totally wrong way of ending a CQ is as follows: 'CQ 20 CQ 20 from G3ZZZ golf three zulu zulu zulu calling CQ, G3ZZZ calling CQ 20, QRZ', or '...calling CQ 20 and standing by. QRZ'.
- If you call CQ and want to listen on another frequency than the one you transmit on, end **each CQ** by indicating your listening frequency, e.g. '...listening 5 to 10 up' or also '...listening on 14295', etc. Just saying 'listening up' or 'up' is not sufficient, as you don't say where you are listening. This method of making QSOs is called *split frequency* working.
- If you intend to work *split frequency*, always check if the frequency you plan to use for listening is free, as well as the frequency on which you will call CQ.
- Saying 'CQ from Victor Romeo two Oscar Portable' is not very clear. Either VR2OP calls CQ using an incorrect spelling phonetic, or VR2O/p calls CQ and omits to add the expression 'stroke' while calling CQ. This can lead to a lot of confusion. Always use the term 'stroke' when you are portable, mobile etc.

II.8.2. What does 'CQ DX' mean?

- If you want to contact *long distance* stations, call 'CQ DX'.
- What is **DX**?
- On HF: stations outside your own continent, or of a country with very limited amateur radio activity (e.g. Mount Athos, Order of Malta etc. in Europe).
- On VHF-UHF: stations located at more than approx. 300 km.
- During a CQ you can insist that you only want to work DX stations, as follows: 'CQ DX, outside Europe, this is…'.
- Always be obliging; maybe the local station calling you after your CQ DX is a newcomer, and maybe you are a *new country* for him. Why not just give him a quick QSO?

II.8.3. Calling a specific station

- Let us assume that you want to call DL1ZZZ with whom you have a *sked* (*schedule, rendez-vous*). Here's how you do this: 'DL1ZZZ, DL1ZZZ this is G3ZZZ calling on sked and listening for you*'.*
- If, despite your directive call someone else calls you, remain polite. Give him a quick report and say 'sorry, I have a sked with DL1ZZZ…'.

II.8.4. How do you make a QSO in phone?

- Assume you get a reply to your CQ call, e.g.: 'G3ZZZ from W1ZZZ, whiskey one zulu zulu zulu is calling you and listening' or 'G3ZZZ from W1ZZZ, whiskey one zulu zulu zulu **over**'.
- We have explained why you cannot end your CQ with 'over' (§ II.8.1). When someone answers your CQ, he wants to turn it over to you (get an answer from you), which means that he can end his call with 'over' (meaning 'over to you').
- If a station answers your CQ, the first thing you need to do is to acknowledge his call, after which you can right away tell him how you are receiving his transmission, give him your name and *QTH* (location): 'W1ZZZ from G3ZZZ (be careful, keep the right sequence!), thanks for the call, I am receiving you very well, readability 5 and strength 8 (usually the indication on the S-meter on your receiver). My QTH is London and my name is John (not '*my personal name'* nor *'my personal'* nor *'my first personal*'; there are no such things as *personal* or *impersonal* names). 'How do you copy me? W1ZZZ from G3ZZZ. Over'.
- If you call a station that has called CQ (or QRZ), call that station by giving his call not more than once. In most cases it's better not to give it at all; the operator knows his own call. In a contest (§ II.8.6) you never give the callsign of the station you are calling.
- In phone we exchange an RS report, a report of <u>R</u>eadability and of signal <u>S</u>trength.
- We have already said not to overly use the Q code in phone contacts, but if you use it, do it correctly. *Q<u>R</u>K* means *<u>R</u>eadability of the signal*, which is the same as R in the <u>R</u>S report. Q<u>S</u>A means *Signal <u>S</u>trength* as the S from the R<u>S</u> report.
  - One thing is different however, the range of the S in the RS report goes from 1 to 9, in the QSA code it goes from 1 to 5 only.
  - So, don't say 'you're QSA 5 and QRK 9' (as we sometimes hear), but if you want to use Q code, say: 'you are QRK 5 and QSA 5'. Of course it is much

simpler to say 'you're 5 and 9'. On CW the use of QRK and QSA is almost non-existent. In CW only the RST report is used instead (§ II.9.6).

READABILITY		SIGNAL STRENGTH	
R1	Unreadable	**S1**	Faint signals, barely perceptible
R2	Barely readable	**S2**	Very weak signals
R3	Readable with difficulty	**S3**	Weak Signals
R4	Readable with no difficulty	**S4**	Fair signals
R5	Perfectly readable	**S5**	Fairly good signals
		S6	Good signals
		S7	Fairly strong signals
		S8	Strong signals
		S9	Very strong signals

- Using the word 'over' at the end of your *over* is recommended but not really a must. A QSO consists of a number of transmissions or *overs*. 'Over' stands for 'over to you'.
- If signals are not very strong and if the readability is not perfect, you can spell out your name etc. Example: 'My name is John, spelled juliett, oscar, hotel, november ...' Do NOT say '...juliett juliett, oscar oscar, hotel hotel, november november'. This is **not** the way you spell the name **John**.
- In most short, so-called rubber stamp QSOs, you will describe your station and antenna and often other data such as weather info (related to propagation especially on VHF and higher) can be exchanged. As a rule it is the station that was first on the frequency (e.g. the station who called CQ) that should take the initiative to bring up subjects of conversation. Maybe he just wants a shorts *hello and good by* contact.
- Use the correct terminology when describing your station. Do not say 'I am working with 5 Whiskey...'. This certainly is not standard ham language. Simply say: "I am running 5 Watts".
- Even during a stereotype QSO we often see technical discussions being developed and results of experimentation being exchanged, just as we would do during *eyeball conversations*. Worth mentioning as well is that many friendships have been forged as a result of radio contacts between hams. The hobby is a real bridge builder between communities, cultures and civilizations!
- If you wish to **QSL** (exchange cards), mention it: 'Please QSL. I will send my card to you via the QSL bureau and would appreciate your card as well'. A QSL is a postcard sized report confirming a QSO you made.
- QSL cards may be mailed directly to the other station or sent via a QSL bureau. Just about all Radio Societies, members of IARU, exchange QSL cards for their members. Some stations only QSL via a QSL manager who handles the mail for him/her. Details of those can be found on various websites.
- Ethics require that hams should be willing to exchange QSL cards without asking money for it other than to cover return postage charges if a direct exchange is requested.
- To wrap up a QSO: '...W1ZZZ, this is G3ZZZ signing with you and listening for any other calls', or if you intend to go off the air '...and closing down the

station'.

- You may add the word 'out' at the end of your last transmission, indicating you are closing down, but it is seldom done. Do NOT say 'over and out', because 'over' means you switch over to your correspondent, and in this case there is no longer a correspondent!

Typical SSB QSO for the beginner:

Is this frequency in use? This is W1ZZZ

Is this frequency in use? This is W1ZZZ

CQ CQ CQ from W1ZZZ whiskey one zulu zulu zulu calling CQ and listening

W1ZZZ from ON6YYY oscar november six yankee yankee yankee calling and standing by

ON6YYY from W1ZZZ, good evening, thanks for your call, you are 59. My name is Robert, I spell Romeo Oscar Bravo Echo Romeo Tango and my QTH is Boston. How copy? ON6YYY from W1ZZZ. Over.

W1ZZZ from ON6YYY, good evening Robert, I copy you very well, 57, readability 5 and strength 7. My name is John, Juliette Oscar Hotel November, and my QTH is near Ghent . Back to you Robert. W1ZZZ from ON6YYY. Over.

ON6YYY from W1ZZZ, thanks for the report John. My working conditions are a 100 Watt transceiver with a dipole 10 meter high. I would like to exchange QSL cards with you, and will send you my card via the bureau. Many thanks for this contact, 73 and see you soon again, I hope. ON6YYY from W1ZZZ.

W1ZZZ from ON6YYY, all copied 100%, on this side I am using 10 Watt with an inverted-V antenna with the apex at 8 meters. I will also send you my QSL card via the bureau, Robert. 73 and hope to meet you again soon. W1ZZZ this is ON6YYY clear with you.

73 John and see you soon from W1ZZZ now clear (…and listening for any stations calling)

II.8.5. Fast back and forth switching

- If you are involved in a quick back and forth conversation, involving short transmissions, you do not need to identify at each *over*. One must identify at least once every 5 minutes (in some countries 10 minutes) as well as at the beginning and at the end of your *transmissions* (can be a series of QSOs).
- You can also turn it over to your correspondent by simply saying 'over', meaning you turned the microphone over to him/her to start his transmission. Even faster is to just stop talking and pause. If the pause exceeds 1 or 2 seconds your correspondent will simply start transmitting.

II.8.6. How to make QSOs in a phone contest?

- ***Contest*** is the name for a radio communication competition between radio amateurs.
- **What is Contesting**? It is the competitive side of Ham Radio.
- **Why contesting**? Contests are competitions in which a radio amateur can measure the competitive performance of his station and antennas, as well as his performance as an operator. As the English say: *the proof of the pudding is in the eating*.
- **How to become a good contester**? Most champion contesters started working contests on a local level. Like in all sports you can only become a champion through lots of exercising.
- **Are there many contests**? There are contests every weekend, totaling well over 200 contests every year. About 20 have the status of important international contests (ham radio's equivalent to Formula 1 racing).
- **Contest calendar**: see various internet sites such as http://ng3k.com/Contest/.
- In most contests the competitors should make as many contacts as possible with e.g. as many as possible different countries (or States, radio zones etc.): these are the so-called **multipliers** which will be used together with the number of QSOs to calculate your score. Big international contests run for 24 or 48 hours, some small local contests only last 3 or 4 hours. Plenty of choice!
- Contests are organized on most bands, HF through SHF.
- There are no contests on the so-called WARC bands: 10 MHz, 18 MHz and 24 MHz. This is because these bands are quite narrow. Contesting would render these bands too crowded to be enjoyable for other users.
- In a contest a valid QSO is made when a callsign, a signal report and often a serial number (or radio zone, locator, age etc.) are exchanged.
- Contest operating is all about **speed**, **efficiency** and **accuracy**. One is expected to say only and exactly what's strictly required. This is not the time for showing you are well educated, and 'thank you', '73', 'see you later' etc. are just not said in a contest. It's all a waste of time.
- If you are new to contesting, it is advisable to first visit a contester during a contest. You can also make your first steps in contesting by participating e.g. in a field day with your local radio club.
- If you decide to try your first contest, start by listening for half an hour (longer is better) to see how the routine contesters go about it. Identify the right procedures to make fast contacts. Be aware that not all that you will hear are good examples. A few examples of common errors are discussed further on.
- An example of a fully efficient contest CQ is: 'G3ZZZ golf three zulu zulu zulu contest'. Always give your call twice, once phonetically, unless you're in a big pileup, in which case you give your call just once and forget about spelling it out very time. Why is the word *contest* the last word in your contest CQ? Because by doing so, someone who happens to tune across your frequency at the end of the CQ, knows there is someone calling CQ contest on that frequency. Even the word *CQ* is left out as it is ballast and contains no added information. Assume you give your call at the end (instead of the word *contest*): in this case the station tuning across the frequency copied your call (he checks in his log whether he needs you or not; assume he does), but he

does not know if you are just working a station or calling CQ. In this case he will have to wait one round to find out, which is a waste of time. That's why you should use the word 'contest' at the end of your (contest) CQ.

- The caller should call you by giving his call just once. Example: 'golf three x-ray x-ray x-ray'. If you do not reply to him within a second, he will give his call again (just once).
- If you copied his call, you will immediately reply as follows: 'G3XXX 59001' or even faster 'G3XXX 591' (check if the contest rules accept the short number where you leave out the leading zeros). In most contests you will have to exchange a RS report and a serial number (in the above example 001 or simply 1). That is the complete exchange; all the rest is ballast.
- If you (G3ZZZ) copied only a partial call (e.g. ON4X..), go back to him as follows: 'ON4X 59001'. Do not send 'QRZ ON4X' or anything like that. You have identified the station you want to work, so go ahead with his partial call. Any other procedure will make you lose time. Being a good operator, ON4XXX will return to you with 'ON4XXX x-ray x-ray x-ray, you are 59012'.
- Never say 'ON4XXX please copy 59001', nor 'ON4XXX copy 59001' which is equally bad. The 'please copy' or 'copy' contains no additional information.
- Being an experienced contester, ON4XXX will come back as follows: '59012'. If he had not copied the report he would have said 'report again' or 'please again'.
- This means neither 'thanks 59012' nor 'QSL 59012' nor 'roger 59012', things that are often being said by less experienced contesters.
- All that's left to be done is to round off the contact as follows: 'thanks G3ZZZ contest' (*thanks* is shorter and faster than *thank you*). By saying this you do 3 distinct things: you end your contact (*thanks*), you identify yourself for stations wanting to call you (*G3ZZZ*), and you call CQ (*contest*). Utmost efficient!
- Do not end with 'QSL QRZ'. Why? 'QSL QRZ' does not tell anything about your identity (call). And you want all passers-by that stumble across your frequency at the end of your QSO, to know who you are and that you are calling CQ-contest. Therefore always end with 'thanks G3ZZZ contest' (or 'QSL G3ZZZ contest') or if you are very much in a hurry 'G3ZZZ contest' (this may however lead to confusion and sounds less friendly). 'QSL' means: *I confirm.* Don't say 'QRZ' because QRZ means 'who called me', unless there were more stations calling you in the first place when you picked out G3XXX.
- There are of course some possible variations to this scheme, but essential to this all is: speed, efficiency, accuracy and the correct use of the Q code.
- Most contest operators use a computer contest logging program. Make sure you have thoroughly tested and tried out the program before using it in real life.
- Apart from calling CQ in a contest to make QSOs you could search the bands looking for so-called *multipliers* or stations you have not worked yet. This is called *search and pounce*. How do you go about this? Make sure you are exactly zero beat with the station you want to work (watch the RIT!). Just give your call **once**. Don't call as follows: 'DL1ZZZ from G3ZZZ'; DL1ZZZ certainly knows his call, and knows you are calling **him** because you call on **his** frequency!
- So, give your call one time. If he does not return to you within 1 second, call again (1 time) etc.

Example of a contest QSO on phone:

whiskey one zulu zulu zulu contest (CQ contest by W1ZZZ)

oscar november six zulu zulu zulu (ON6ZZZ answers)

ON6ZZZ five nine zero zero one (W1ZZZ gives a report to ON6ZZZ)

five nine zero zero three (ON6ZZZ gives his report to W1ZZZ)

thanks W1ZZZ contest (W1ZZZ finishes the contact, identifies and calls CQ contest)

- During some of the larger international contests (CQWW, WPX, ARRL DX, CQ-160m contest –all of these in phone as well as in CW-), contest operators not always fully live by the IARU Band Plan. This happens almost exclusively on 160m and 40m, because of the restricted space on those bands. It is nice however to see that during these contests many thousand of hams intensively occupy our bands, which is very positive in view of our required band occupation (use them or lose them). The temporary nuisances caused by this exceptional situation, should best be approached with a positive attitude.

II.8.7. The correct use of 'QRZ'

- 'QRZ' means 'who called me?', nothing more, nothing less.
- The most classical use of 'QRZ' is after a CQ, when you were unable to copy the call(s) of the station(s) that called you. In a way it means 'I am sorry, I heard you calling me, but could not get your call. Please call again'.
- It does not mean 'who's there?' neither does it mean 'who's on the frequency?' and even less 'please call me'.
- If someone comes on an apparently clear frequency and wants to check whether or not it is in use, he should not use 'QRZ?' to do that! Just ask 'is this frequency in use?'.
- If you have been listening to a particular station which has not identified for some time and you would like to know his call, you can ask 'your call please' or 'please identify'. Strictly spoken you would need to add your callsign, because you need to identify yourself.
- 'QRZ' certainly does NOT mean 'call me please'. We more and more frequently hear CQ calls ending in the word 'QRZ'. This makes no sense. How can someone already have been calling if you just finished a CQ?
- Another incorrect use of 'QRZ': I am calling CQ in a contest. A station tunes across my frequency and just catches the tail end of my CQ, but missed my callsign. We often hear stations in such circumstances say 'QRZ'. Totally wrong. Nobody has called this station. All he has to do is to wait for my next CQ to find out my call! The same remark applies to CW of course.
- Other similar rather funny but incorrect expressions are: 'QRZ is this frequency in use?' or 'QRZ the frequency' (should be 'is this frequency in use?').
- One more rather widespread incorrect use of 'QRZ': 'CQ DX CQ this is UR5ZZZ QRZ DX'. Just say ''CQ DX CQ this is UR5ZZZ calling CQ DX and listening'.
- Another incorrect use of QRZ: 'give me your QRZ' which is supposed to mean

'give me your call'. It is remarkable that in most of the above erroneous uses of "QRZ" there is a link to the idea of "callsign". But please, do use 'QRZ' in the one and only meaning it has: 'who called me'

- During pileups (see § III.1) we will often hear the DX station saying 'QRZ', not because in the first place he previously missed a call but to tell the pileup he is listening again. This use of 'QRZ' is not quite correct.

Example:

CQ ZK1DX	ZK1DX calls CQ
ON4YYY you're 59	ON4YYY calls ZK1DX who replies with a report
QSL **QRZ** ZK1DX	ZK1DX confirms the report ('QSL') and adds 'QRZ', which in this case means '*I am listening again for the stations calling me* rather than *who called me?'* which is the real meaning of 'QRZ'. Although you could argue that he heard other stations before and hence can call 'QRZ', the use of 'QRZ' followed by 'ZK1DX' is certainly not the most efficient procedure.

What we hear even more and which is completely wrong:

...	
QSL **QRZ**	in this case ZK1DX does not identify at all. The pileup wants to know who the DX station is.

The correct and most efficient procedure is as follows:

...	
QSL ZK1DX	ZK1DX confirms the report he received by saying 'QSL'. This is followed by his call, which is the sign for the pileup to call him.

II.8.8. Check your transmission quality

- Have you properly adjusted your transmitter?
- Is the microphone gain not set too high?
- Is the speech processing level not too high? The background noise level should be at least 25 dB down from your voice peak level. This means that when you don't speak the output level of the transmitter must be at least approximately 300 times lower than the peak power when you speak.
- Ask a local ham to check your transmission for *splatter*.
- Having an oscilloscope in line with the output signal so you can monitor for flat topping is the best continuous monitoring system.

II.9. THE ART OF TELEGRAPHY (CW, MORSE CODE)

- Morse code is a code for transmitting text. The code is made up by sequences of short and long audio tones. A short tone burst is called a **DIT**, the longer one a ***DAH***. The *DAHs* are 3 times as long as the *DITs*. These are frequently but

incorrectly called *DOTS* and *DASHES*, which make us think of something visual rather than sounds.

- Morse code is **not** a series of written *DOTS* and *DASHES*, although originally, in the 19th century, Morse code was scribed as *DOTS* and *DASHES* on a moving paper strip. Telegraph operators soon found out it was easier to copy the text by listening to the buzz of the scriber machine than trying to read it off the paper strips. So the letter '**R**' is **not** *SHORT LONG SHORT* nor *DOT DASH DOT*, nor **. - .** but ***DIT DAH DIT***.
- In some languages the letter '**R**' will be written as **DIT DAH DIT**, in others as **DI DAH DIT**. What we are trying to make clear is that there are only two sounds, the short sound (**DIT** or **DI**) and the long sound (**DAH**). Representing two sounds by three words may be confusing; therefore we use only **DIT** and **DAH** in this document.
- CW makes extensive use of *Q codes*, *abbreviations* and *prosigns*. These are all shortcuts to make communicating faster and more efficient.
- Hams normally use the word ***CW*** for telegraphy. The term *CW* stems from *Continuous Wave* although CW is far from being a *continuous wave*, but rather a wave which is constantly interrupted at the rhythm of the Morse code. Hams use the terms *Morse* and *CW* interchangeably – they mean the same thing.
- The -6dB bandwidth of a properly shaped CW signal is approximately 4 times the sending speed in WPM (<u>W</u>ords <u>P</u>er <u>M</u>inute). Example: CW at 25 WPM takes 100 Hz (at -6dB). The spectrum required to transmit one SSB (voice) signal (2,7 kHz) can hold more than a dozen CW signals!
- The intrinsic narrow bandwidth of CW results in a much better Signal-to-Noise ratio under marginal conditions as compared to wide band signals such as SSB (a wider bandwidth contains more noise power than a narrower bandwidth). This is why DX contacts under marginal conditions (e.g. working stations in other continents on 160m and working EME) are most frequently done in CW.
- What's the minimum receiving speed you need to master to be able to regularly make QSOs in Morse code?

  - 5 WPM can get you a starter's certificate, but you will not be able to make many contacts except on the special *QRS* (*QRS* means: reduce your sending speed) frequencies. These *QRS* frequencies can be found in the IARU Band Plan.
  - 12 WPM is a minimum, but most experienced CW operators make their QSOs at 20 to 30 WPM and even higher speeds.

- There is no secret recipe to master the **Art** of CW: training, training, training, just as in any sport.
- CW is a unique language, a language which is mastered in all countries of the world!

II.9.1. The computer as your assistant?

- You will **not** learn CW by using a computer program that helps you to decode

CW.

- It is acceptable though to send CW from a computer (pre-programmed short messages). This is commonly done in contests by the logging program.
- As a newcomer you may want to use a CW decoding program to **assist** you in order to be able to verify that a text was correctly decoded. However, if you really want to learn the code, you will need to decode the same CW text yourself using your ears and brain.
- CW decoding programs perform very poorly under anything but perfect conditions; our ears and brains are far superior. This is mainly because Morse code was not developed to be automatically sent nor received, as is the case with many modern digital codes (RTTY, PSK etc.).
- A large majority of **CW operators** use an electronic keyer (with a paddle) instead of a hand key to generate Morse code. It is much easier to send *good* Morse code using an electronic keyer than with a hand key.

II.9.2. Calling CQ

- What should you do first of all?
  - Decide which band you will use. On which band is there good propagation for the path you want to cover? The monthly MUF charts, published in magazines and on many ham websites can be very helpful in this respect.
  - Check which band portions are reserved for CW work. On most bands this is at the bottom end of the bands. Consult the **IARU Band Plan** on the IARU website.
  - Listen for a while on the frequency you would like to use to find out whether it is clear or not.
  - And then?
  - If the frequency seems clear, ask if the frequency is in use. Send 'QRL?' at least twice, with a few seconds in between. Sending '?' only is not the proper procedure. The question mark just says 'I asked a question'; the problem is that you did not ask anything.
  - 'QRL?' (with the question mark) means 'is this frequency in use?'.
  - Do not send 'QRL? K' as we sometimes hear. It means 'is the frequency in use? Over to you'. To whom? Just 'QRL?' is correct.
  - If the frequency is in use, someone will answer 'R' (roger), 'Y' (yes), or 'R QSY', or 'QRL', 'C' (I confirm) etc.
  - 'QRL' (without question mark) means: the frequency **is** in use.
    In such a case you will have to look for another frequency to use.
- And if a clear frequency was found?
- Call CQ. How?
- Send CQ at the speed at which you would like to be answered. Never send faster than you can copy.
- 'CQ CQ G3ZZZ G3ZZZ G3ZZZ AR'.
- 'AR' means 'end of message' or 'I am through with this transmission', while 'K' means 'over to you' etc. This means you should always terminate your CQ with 'AR' and never with 'K', because there is nobody there yet whom you can turn it over to.
- Do **not** end your CQ with 'AR K': it means 'end of message, over to you'. There is nobody to turn it over to yet. End your CQ with 'AR'. It is true that we often

hear 'AR K' on the band, but it is not a proper procedure!

- The use of 'PSE' at the end of a CQ (e.g. 'CQ CQ de... PSE K') may seem to be very polite, but is not necessary. It has no added value. In addition, the use of the 'K' is incorrect. Simply use 'AR' at the end of your CQ.
- Send your call 2 to 4 times, certainly not more!
- Don't send an endless series of CQs, with your call just once at the end. Thinking that a long CQ will increase the chances of getting a response is wrong. It actually has the opposite effect. A station that may be interested in calling you first wants to know your call, and certainly is not interested in listening to an almost endless series of CQ CQ CQ ...
- It's much better to send a number of short CQs ('CQ CQ de F9ZZZ F9ZZZ AR') than one long spun CQ ('CQ CQ CQ ... -15 times- de F9ZZZ CQ CQ CQ ... -15 more times- de F9ZZZ AR').
- If you call CQ and want to work *split* (listening on another frequency than you transmit on), specify your listening frequency **at each CQ**. Example: end your CQ with 'UP 5/10...' or 'UP 5...' or 'QSX 1822...' (which means that you will listen on 1.822 kHz). 'QSX' means 'I listen on ...'.

II.9.3. Prosigns

- **Prosigns** (short for *procedural signs*) are symbols formed by combining two characters into one *without the inter-character space*.
- 'AR', used to end a transmission, is a *prosign*.
- Other commonly used prosigns are:
  - 'AS' (see § II.9.9)
  - 'CL' (see § II.9.6)
  - 'SK' (see § II.9.6)
  - 'HH' (see § II.9.20)
- 'BK' (see § II.9.7) and 'KN' (see § II.9.10) are **not** prosigns, as the two letters of these codes are sent with a space in between.

II.9.4. Calling 'CQ DX'

- Just send 'CQ DX' instead of 'CQ'. If you want to work DX from a specific region, call e.g. 'CQ **JA** CQ **JA** I1ZZZ I1ZZZ **JA** AR' (a call for stations from Japan), or 'CQ **NA** CQ **NA**...' (a call for stations from North America) etc. You can also make your CQ DX call more explicit by adding that you do not want to contact European stations: 'CQ DX CQ DX I1ZZZ I1ZZZ DX **NO EU** AR', but this sounds a little aggressive.
- You can also specify a continent: NA = North America, SA = South America, AF = Africa, AS = Asia, EU = Europe, OC = Oceania.
- Even if a station from your own continent calls you, always remain courteous. Maybe he is a newcomer. Give him a quick contact and log him. You may actually be a new country for him!

II.9.5. Calling a specific station (a directive call)

- Let us assume that you want to call DL0ZZZ, with whom you have a *sked* (*schedule*, *rendez-vous*). Here's how you do this: 'DL0ZZZ DL0ZZZ SKED DE G3ZZZ KN'. Note the 'KN' at the end, which means you do not want other stations to call you.

- If, despite your directive call someone else calls you, give him a quick report and send 'SRI HVE SKED WID DL0ZZZ 73…'.

II.9.6. Carry on and wrap up the CW QSO

- Assume W1ZZZ is answering your CQ: 'G3ZZZ DE W1ZZZ W1ZZZ **AR**', or 'G3ZZZ DE W1ZZZ W1ZZZ **K**' or even 'W1ZZZ W1ZZZ **K**' or 'W1ZZZ W1ZZZ **AR**'.
- While replying to a CQ, do not send the call of the station you are calling more than once, better still is not to send it at all (you can trust the operator knows his own call…).
- Should the calling station end its call with 'AR' or 'K'? **Both are equally acceptable**. 'AR' means 'end of message' while 'K' means 'over to you'. The latter sounds a little more optimistic, as maybe the station you call will return for another station…
- There is however a good reason to use 'AR' rather than 'K'. 'AR' is a prosign (see § II.9.3) which means that the letters A and R are sent without any space between them. If one sends 'K' instead of 'AR' and if the letter 'K' is sent somewhat close to the callsign, the letter 'K' may be considered as being the last letter of the call. It happens all the time. With 'AR' this is quite impossible as 'AR' is not a letter. Often no closing code (neither AR nor K) is used, which reduces the risk of making errors.
- Assume you want to reply to W1ZZZ who called you. You can do that as follows: 'W1ZZZ DE G3ZZZ GE (good evening) TKS (thanks) FER (for) UR (your) CALL UR RST 589 589 NAME BOB BOB QTH LEEDS LEEDS HW CPY (how copy) W1ZZZ DE G3ZZZ K'. This is the time to use 'K' at the end of your transmission. 'K' means *over to you*, and now the *you* is W1ZZZ.
- Do not end your *over* with 'AR K': it means 'end of message, over to you'. It is clear that when you turn it over you have finished your message, no need to say so. End your transmissions (*overs*) during a QSO with 'K' (or 'KN' when necessary, see § II.9.10). True, we hear 'AR K' frequently, but it is incorrect.
- The reason for the improper uses of either 'AR', 'K', 'KN', 'AR K', or 'AR KN', is that many operators do not really know what each of these prosigns exactly mean. Let's use them properly!
- We explained that it is not necessary to use the term 'PSE' (*please*) to end a CQ; do not use it either at the end of your *over*. So no 'PSE K' or 'PSE KN'. Let's keep it simple, and leave out the 'PSE', please…
- On the VHF bands (and higher) it is customary to exchange the QTH-locator. This is a code indicating the geographic location of your station (example: JM12ab).
- The **RST report**: R and S stand for Readability (1 to 5) and signal Strength (1 to 9) as used for phone signals (see § II.8.4). The T (1 to 9) in the signal report stands for Tone. It indicates the pureness of the sound of the CW signal, which should sound like a pure sine wave signal without any distortion.
- These original tone ratings attributed to the different T values stem from the early days of amateur radio where often a pure CW tone was an exception rather than the rule. The above table lists the more modern CW tone ratings as published in 1995 (source: W4NRL).

T 1	60 Hz (or 50 Hz) AC or less, very rough and broad
T 2	Very rough AC, very harsh
T 3	Rough AC note, rectified but not filtered
T 4	Rough note, some trace of filtering
T 5	Filtered rectified AC, but strongly ripple-modulated
T 6	Filtered tone, definite trace of ripple modulation
T 7	Near pure tone, trace of ripple modulation
T 8	Near perfect tone, slight trace of modulation
T 9	Perfect tone, no trace of ripple or modulation of any kind

- In practice we generally use just a few levels of T with a definition which meets the general status of technology today:
  - **T1**: heavily modulated CW, signs of wild oscillation or extremely rough AC (means: get off the air with such a poor signal!).
  - **T5**: very noticeable AC component (often due to poor regulation of a power supply of the transmitter or amplifier).
  - **T7 – T8**: slightly or barely noticeable AC component.
  - **T9**: perfect tone, undistorted sine waveform.
- /Nowadays the most common CW signal deficiencies are **chirp** and even more common **key clicks** (see § II.9.25).
- A long time ago chirp and key clicks were very common problems with CW signals: every CW operator knew that a 579**C** report meant signals exhibiting chirp, and 589**K** meant signals with key clicks. Few hams nowadays know what the C and the K at the end of an RST report stand for, so better send 'CHIRP' or 'BAD CHIRP', and 'CLICKS' or 'BAD CLICKS' in full words as part of your report.
- A typical way to gracefully end the QSO would be: '...TKS (thanks) FER QSO 73 ES (=and) CUL (see you later) W1ZZZ de G3ZZZ SK'. 'SK' is the prosign meaning 'end of contact'.
- 'DIT DIT DIT DAH DIT DAH' is the prosign 'SK' (from 'stop keying') and not 'VA' as published in some places (SK sent without inter letter spacing sounds the same as VA sent without inter letter spacing).
- Do not send '...AR SK'. It does not make sense. You are saying 'end of transmission' + 'end of contact'. It is quite obvious the end of your contact is at the end of your transmission. You will quite often hear '...AR SK', but the AR is redundant, so avoid using it.
- If at the end of the QSO you also intend to close down your station, you should send: '...W1ZZZ DE G3ZZZ SK CL' ('CL' is a prosign meaning 'closing' or 'closing down').

Typical CW QSO for the beginner:

QRL?

QRL?

CQ CQ G4ZZZ G4ZZZ CQ CQ G4ZZZ G4ZZZ AR

G4ZZZ DE ON6YYY ON6YYY AR

ON6YYY DE W4ZZZ GE TKS FER CALL UR RST 579 579 MY NAME BOB BOB QTH HARLOW HARLOW HW CPY? ON6YYY DE W1ZZZ K

G4ZZZ DE ON6YYY FB BOB TKS FER RPRT UR RST 599 599 NAME JOHN JOHN QTH NR GENT GENT W1ZZZ DE ON6YYY K

ON6YYY DE G4ZZZ MNI TKS FER RPRT TX 100 W ANT DIPOLE AT 12M WILL QSL VIA BURO PSE UR QSL TKS QSO 73 ES GE JOHN ON6YYY DE G4ZZZ K

G4ZZZ DE ON6YYY ALL OK BOB, HERE TX 10 W ANT INV V AT 8M MY QSL OK VIA BURO 73 ES TKS QSO CUL BOB G4ZZZ DE ON6YYY SK

73 JOHN CUL DE G4ZZZ SK

- An overview of the *closing codes*:

CODE	MEANING	USE
AR	end of transmission	at end of CQ **and** at the end of your transmission when you call a station (1)
K	over to you	at the end of an *over* (2) **and** at the end of your transmission when you call a station (1)
KN	over to you only	at the end of an *over*
AR K	end of transmission + over to you	**do NOT use**
AR KN	end of transmission + over to you only	**do NOT use**
SK	end of contact (end of QSO)	at end of QSO
AR SK	end of transmission + end of contact	**do NOT use**
SK CL	end of QSO + closing down station	when closing down

(1) when you reply to a station calling CQ or QRZ
(2) a transmission or an over is NOT the same as a QSO (contact). A QSO usually consists of a series of overs

II.9.7. Using 'BK'

- 'BK' (*break*) is used for switching quickly back and forth between stations without exchanging callsigns at the end of the transmission. In a way it is the CW equivalent of 'over' in phone.
- Example: W1ZZZ wants to know the name of G3ZZZ he's in contact with and sends: '...UR NAME PSE BK'. G3ZZZ answers immediately: 'BK NAME JOHN JOHN BK'.
- The break is announced with 'BK', and the transmission by the correspondent starts with 'BK'. The latter *BK* however is not always sent.

II.9.8. Still faster

- Often even the 'BK' code is not used. One just stops sending (in *break in* mode, which means that you can listen between words or characters) giving an opportunity to the other station to start sending, just as in a normal face to face conversation, where the word is also passed back and forth without any formality.

II.9.9. Using the prosign 'AS' (DIT DAH DIT DIT DIT)

- If, during a QSO, someone *breaks in* (transmits his call on top of the station you are working, or gives his call when you switch over), and you want to let him know that you first want to finish the QSO, just send 'AS', which means 'hold on', 'wait' or 'stand by'.

II.9.10. Using 'KN'

- 'K' = 'over'. Sending just 'K' at the end of your over leaves the door open for other stations to break in. If you don't want to be interrupted, send 'KN'.
- 'KN' means that you want to hear ONLY the station whose callsign you just sent (= 'go ahead, others keep out' or 'over to you only'), in other words: no breakers at this time please.
- 'KN' is mainly used when chaos is around the corner. A possible scenario: different stations are coming back to your CQ. You are decoding one partial call and you send: 'ON4AB? DE G3ZZZ PSE UR CALL AGN (again) K'. The station *ON4AB?* answers you, but in addition several other stations call simultaneously, making it impossible to copy his call. The procedure is to call *ON4AB?* again and end your call with 'KN' instead of 'K', this to emphasize you only want to hear *ON4AB?* come back to you. Example: 'ON4AB? DE G3ZZZ KN' or even 'ONLY ON4AB? DE G3ZZZ KN'. If you are still short of authority on the frequency you may try 'ON4AB? DE G3ZZZ KN N N N' (keep some extra space between the letters N). Now you are really getting nervous...

II.9.11. How to answer a CQ

Assume W1ZZZ has called CQ and you want to make a QSO with him. How do you go about it?

- Do not send at a higher speed than the station you're calling.
- Do not send the call of the station you are calling more than once; most of the time the call is not sent, it is obvious who you are calling.
- You can use either 'K' or 'AR' to end your call (see § II.9.6): 'W1ZZZ DE G3ZZZ G3ZZZ K', 'G3ZZZ G3ZZZ K', 'W1ZZZ DE G3ZZZ G3ZZZ AR' or 'G3ZZZ G3ZZZ AR'.
- In many cases one sends only the callsign without any *closing code* (AR or K) at all. This is also common practice in contests.
- Do not end your call with either '...**PSE** AR' or '...**PSE** K' (see § II.9.6).

II.9.12. Someone sends an error in your call

- Assume W1ZZZ has not copied all the letters of your call correctly. His answer is something like: 'G3ZZ**Y** DE W1ZZZ TKS FOR CALL UR RST 479 479 NAME JACK JACK QTH NR BOSTON BOSTON G3ZZ**Y** DE W1ZZZ K'.
- Now you go back to him as follows: 'W1ZZZ de G3ZZZ ZZZ G3ZZZ TKS FER

RPRT…'. By repeating part of your call a few times, you emphasize this part of the call to get your correspondent's attention so he can correct the error.

II.9.13. Call a station that's finishing a QSO

- Two stations are in QSO, the QSO comes to an end. If they both sign with 'CL' ('closing down') it means the frequency is now clear as they both closed down. If one or both ended with 'SK' (end of transmission), it may well be so that one or the other will remain on frequency for more QSOs (in principle the station that initially called CQ on that frequency).
- In this case, it is best to wait a while and see if either one calls CQ again.
- Example: W1ZZZ finished a QSO with F1AA: '…73 CUL (see you later) F1AA de W1ZZZ SK'.
- As neither one calls CQ after the QSO, you can call either one.
- Assume you (G3ZZZ) want to call F1AA. How do you go about it? Simply send 'F1AA de G3ZZZ G3ZZZ AR'.
- In this case calling without mentioning the callsign of the station you want to contact would be inappropriate. Send the call of the station you want to work once, followed by your call once or twice.

II.9.14. Using the '=' sign or 'DAH DIT DIT DIT DAH'

- Some call it 'BT', because it is like a letter B and T sent without space (like 'AR' is sent without space), but simply is the equality sign (=) in CW.
- DAH DIT DIT DIT DAH is used as a ***filler*** to pause for a second while you think of what you are going to send next. It is also used as a ***separator*** between chunks of text.
- As *filler* it is used to prevent your correspondent from starting to transmit, because you haven't finished your sentence yet, or you have not finished sending what you want to send. It is clearly the equivalent of *euh* or *eh*.
- Some CW operators seem to use 'DAH DIT DIT DIT DAH' spread all over their QSOs as a *text separator*, to make the text more readable. Example: 'W1ZZZ DE G4YYY = GM = TU FER CL = NAME CHRIS QTH SOUTHAMPTON = RST 599 = HW CPI? W1ZZZ DE G4YYY KN'. The use of this separation mark seems less common nowadays, and is considered by many as a waste of time. 'W1ZZZ DE G4YYY GM TU FER CL NAME CHRIS QTH SOUTHAMPTON RST 599 HW CPI? W1ZZZ DE G4YYY KN' is as readable as the version of the text with the separators.

II.9.15. Send good sounding code

- Listening to your CW should be like listening to good music, where one never feels like *working* at deciphering an unknown code or assembling a puzzle.
- Make sure you *space* letters and words appropriately. Fast sending with a little extra spacing usually makes overall copying easier.
- Experienced CW operators don't listen for letters but for words. This can of course only be done successfully if the right spacing exists between words. Once you start hearing words instead of a stream of letters, you are getting there! In normal face to face conversation we also listen for words, not for letters, don't we?
- On an automatic keyer, adjust the DIT/space ratio (weight) correctly. It will

sound nicest (most pleasing) if the ratio is a little bit on the high side (DIT a little longer than a space), compared to the standard 1/1 ratio.

- Remark: weight is not the same as DIT/DAH ratio! The DIT/DAH ratio is usually fixed at a 1/3 ratio on most keyers (not adjustable).

II.9.16. I am a QRP station (= low power station)

- A **QRP** station is a station transmitting with a power of maximum 5 W (CW) or 10 W (SSB).
- Never send your call as 'G3ZZZ/QRP', this is **illegal** in many countries (e.g. Belgium). The QRP information is **not** part of your callsign, so it cannot be sent as a part of it. In many countries the only permitted call suffixes are /P, /A, /M, /MM and /AM..
- If you are really a QRP station, chances are that you will be *relatively weak* with the station you are calling. Adding unnecessary ballast (the slash and the letters QRP) to your callsign will make it even more difficult to decipher your callsign!
- You can of course always mention during the QSO you are a QRP station, e.g.: '...PWR 5W 5W ONLY...'.
- If you call CQ as a QRP station and you want to announce that during your CQ, you can do it as follows: 'CQ CQ G3ZZZ G3ZZZ QRP AR'. Insert a little extra space between the call and 'QRP' and do not send a slash (DAH DIT DIT DAH DIT) between your call and 'QRP'.
- If you're looking for QRP stations specifically, call CQ as follows: 'CQ QRP CQ QRP G3ZZZ G3ZZZ QRP STNS (stations) ONLY AR'.

II.9.17. The correct use of 'QRZ?'

- 'QRZ?' means 'who called me?', and nothing else. Use it when you could not quite copy the station (or stations) that called you.
- In CW always send QRZ followed by a **question mark** ('QRZ?'), as is done with all Q codes when used as a question.
- Typical use: after a CQ F9ZZZ was unable to decipher any of the callers. Then he sends: 'QRZ? F9ZZZ'.
- If you have been able to copy part of a call (ON4...), and if more stations were calling you, do not send 'QRZ' but rather 'ON4 AGN (again) K' or 'ON4 AGN KN' ('KN' indicates clearly you only want to hear the ON4 station come back to you). Note that in this case you use 'K' or 'KN' and **not** 'AR' because you turn it back to one station in particular, the ON4 station whose suffix you missed.

Don't send 'QRZ' in this case or all the stations will start calling you again.

- 'QRZ' does **not** mean 'who is there?' or 'who is on the frequency?'. Assume someone passes by a busy frequency and listens in. After quite a while nobody having identified, he wants to find out the calls. The proper way to do so is to send 'CALL?' or 'UR CALL?' (or 'CL?', 'UR CL?'). Using 'QRZ' is inappropriate here. By the way, when you send 'CALL?', you should in principle add your call, otherwise you make an unidentified transmission, which is illegal.

II.9.18. The use of '?' instead of 'QRL?'

- Before using an apparently clear frequency, you need to actively check if no one is there already (maybe you are not hearing one end of a QSO because of propagation).
- The normal procedure is: send 'QRL?' (on CW) or ask 'is this frequency in use?' on phone.
- On CW, some simply send '?', because it is faster and thus potentially creates less QRM if someone else is using that frequency.
- But '?' can be interpreted in many ways (it says: *I am asking a question, but I did not say which one…*). Therefore always use 'QRL?'. Merely transmitting a question mark can create a lot of confusion.

II.9.19. Sending 'DIT DIT' at the end of a QSO

- At the end of a QSO both QSO partners often send as very last code two DITs with some extra spacing between them (like e e). It means and sounds like 'bye bye'.

II.9.20. Correcting a sending error

- Assume you make a sending error. Immediately stop sending, wait a fraction of a second and send the prosign 'HH' (= 8 DITs). Not always easy to send exactly 8 DITs, you're already nervous because you made an error, and now they want you to send exactly 8 DITs: DIT DIT DIT DIT DIT DIT DIT DIT, not 7 nor 9!
- In actual practice, many hams send just a few (e.g. 3) DITs, with extra space in between the DITs: 'DIT _ DIT _ DIT'. These extra spaced DITs indicate that the sender is not sending the code for a letter nor figure.
- Resend the word where you made an error and carry on.
- Often even these 3 DITs are left out altogether. When the sender realizes he's sending an error, he stops for about second and starts sending the same word again.

II.9.21. CW contests

- See § II.8.6 as well.
- Contest means speed, efficiency and accuracy. Hence, send only what's strictly necessary.
- The most efficient contest CQ is as follows: 'GM3ZZZ GM3ZZZ TEST'. The word *TEST* should be placed at the end of the CQ call.
  - Why? Because anyone tuning across the frequency at the end of your CQ then knows that you call CQ.
  - Assume you end your CQ contest call with your callsign: a passer-by noticed he needs that call, but does not know whether you called someone else or

called CQ. So he has to wait one more round to find out: a waste of time.
- Therefore, always end your contest CQ with word *TEST*. Note that even the word *CQ* is left out from a contest CQ as it contains no additional information.

- An experienced contester will come back to your CQ contest call by just giving his call once. Nothing more. Example: 'W1ZZZ'. If you don't get back to him within 1 second, he will likely send his call again unless you returned to someone else.
- You copied his call and reply to him as follows: 'W1ZZZ 599001' or 'W1ZZZ 5991' provided the contest rules admit you to drop the leading zeros. Still faster would be to use *cut numbers* (abbreviated numbers): 'W1ZZZ 5NNTT1' or 'W1ZZZ 5NN1' (see § II.9.22)
- In most contests the exchange consists of a RST report followed by e.g. a serial number. Do not send anything else. No 'K' at the end, no '73', no 'CUL' (see you later), no 'GL' (good luck); there is no room for all of this in a contest where *speed* is the name of the game.
- Ideally W1ZZZ will answer e.g. as follows: '599012' or '5NNT12'.
- If he did not copy your report he would have sent: 'AGN?'. As he did not do that, it means that your report was received OK. No need to send 'TU', 'QSL', 'R' or whatever else to confirm reception of the report. It is a waste of time.
- All that's left to be done is to end the contact. A polite way of doing this: 'TU GM3ZZZ TEST'. *TU* says the QSO is over (thank you), *GM3ZZZ* identifies you for stations wanting to call you and *TEST* is a new CQ contest. If the QSO rate is very high, you can leave out the *TU*.
- There are of course slight variations possible, but the key words are speed, efficiency and accuracy.
- Most contesters use a computer contest program, which in addition to logging also allows them to send CW via pre-programmed short messages (CQ, reports etc.). A separate CW paddle and keyer allows for the operator to manually intervene if necessary. Such a setup makes long contests less tiring and will increase accuracy. Contest logging with pen and paper is almost history.
- If you want to look for *multipliers* or stations you have not yet worked, you will need to scan the band looking for such stations. When you find one, call as follows: 'GM3ZZZ'. Do not send his callsign, it's a waste of time. You can be sure the operator knows his own call. And he also knows you are calling him, because of the timing and of the fact that you give your call on the frequency where he is operating! Also, do not send 'DE GM3ZZZ', the word *DE* contains no additional information.
- If he does not come back within a second, give your call again, etc.

Example of a CW contest QSO:

DL0ZZZ TEST (CQ call from DL0ZZZ)

G6XXX (G6XXX calls DL0ZZZ)

G6XXX 599013 (DL0ZZZ gives G6XXX a report)

599010 (G6ZZZ gives DL0ZZZ his report)

TU DL0ZZZ TEST (DLOZZZ confirms reception and calls CQ Contest)

II.9.22. Abbreviated numbers (cut numbers) used in contests

- The code to be exchanged in most contests consists of a series of numbers, e.g. RST, followed by a 3-digit serial number.
- To save time, the CW code for some numbers (digits) is often shortened (cut):

  1 = A (DIT DAH, instead of DIT DAH DAH DAH DAH)
  2, 3 and 4 are usually **not** abbreviated
  5 = E (DIT instead of DIT DIT DIT DIT DIT)
  6, 7 and 8 are usually **not** abbreviated
  9 = N (DAH DIT instead of DAH DAH DAH DAH DIT)
  0 = T (DAH instead of DAH DAH DAH DAH DAH)

- Example: instead of sending '599009' one could send 'ENNTTN'. Most frequently you will hear '5NNTTN'. As we expect numbers, and although letters are received, we write down numbers. The better computer contest programs allow you to type in letters (in the exchange field); the program will automatically convert these letters to numbers.
- A4 instead of 14 (or a5 instead of 15 etc.): in some contests (e.g. CQ WW) you need to send your CQ zone number as part of the contest exchange. Instead of sending e.g. '59914' we often send '5NNA4' or even 'ENNA4'.

II.9.23. Zero beat

- A major advantage of a CW QSO is the narrow bandwidth such a QSO uses (a few hundred Hz), provided both stations in a QSO transmit on the exact same frequency.
- For most standard contacts, both stations will transmit on one and the same frequency (**simplex** operation). They are said to be ***zero beat*** with one another.
- The term *zero beat* comes from the fact that if two stations transmit on exactly the same frequency, the resulting beat from mixing the two signals would have a frequency of zero Hz: these signals are said to be *zero beat*.
- Often however, they do not transmit on exactly the same frequency. For this there are two major reasons (often a combination of both):
  - One of them is the incorrect use of the RIT (Receiver Incremental Tuning) on the transceiver. Most modern transceivers have an RIT function which makes it possible to listen on a frequency which is (slightly) different from the transmit frequency.
  - A second reason is that the operator does not apply the correct zero beat procedure. With most modern transceivers the zero beat procedure consists of making sure that the pitch of the side tone (CW monitor signal) of the transmitter is at exactly the same frequency as the tone (pitch) of the station you listen to. If you listen at 600 Hz and the side tone pitch is set at

1.000 Hz, you will transmit 400 Hz away from the station you are calling.

- On modern transceivers the frequency of the CW side tone monitor (pitch) is adjustable, and tracks the BFO frequency offset.
- Many experienced CW operators listen at a fairly low beat tone (400 – 500Hz, sometimes even as low as 300 Hz) instead of the more usual 600 – 1,000 Hz. For most people a lower pitch frequency is less tiring during long periods of listening and, in addition it allows for better discrimination between close spaced signals.

II.9.24. Where can one find slow speed CW stations (QRS)?

- 80 m: 3.550 - 3.570 k
- 20 m: 14.055 - 14.060 kHz
- 15 m: 21.055 - 21.060 kHz
- 10 m: 28.055 - 28.060 kHz

- *QRS* means : send more slowly
- *QRQ* means : send faster

II.9.25. Do I have key clicks?

- Not only the content and the format of what you send needs to be OK ... but also the quality of the CW signals you transmit must be good.
- Quality problem # 1 is **key clicks**.
- Key clicks are always shown by the envelope waveform of the transmitted signal looking like a (nearly) perfectly square wave, with no rounded off edges, often including overshoot leading end spikes. All of this results in wide sidebands, which are witnessed as *clicks* left and right of the CW signal. There are three main technical causes for this problem:

  - One is an improperly shaped keying waveform containing a lot of harmonics (square edges). The cause of this is most often a poor circuit design by the manufacturer. Fortunately, a number of circuit changes have been published on internet to solve these problems.
  - The second one is having too much driving power to the amplifier combined with improper ALC (*automatic level control*) action (too slow attack time), resulting in leading edge spikes. It is always recommended to manually adjust the required drive power and not to rely on action of an ALC circuit.
  - A third one is improper open/closure sequence timing of RF relays in full break in.

- How can you detect key clicks generated by your own station? A well experienced ham in your close neighbourhood can listen carefully for clicks.
- Much better is to continuously monitor all transmissions using an oscilloscope displaying the waveform of your transmitted signal.
- Note that even some of the popular fairly recent commercial transmitters have outspoken key clicks.
- If you notice key clicks on your transmission or if you get reports on excessive key clicks, correct the problem or find help to do so. Your key clicks are causing problems with your other hams. Hence getting rid of your key clicks is a question of *ethics*!

II.9.26. Too fast?

- Is the CW speed you master not high enough to be able to make many QSOs?
- To increase your receiving speed, you need to exercise at a speed which is at the limit of your capabilities, where you gradually and constantly increase the speed (à la RUFZ, see § II.8.27).
- Up to approx. 15 WPM you can write down a text sent in CW letter by letter.
- At over 15 or 20 WPM you should recognize words, and write down only what's essential (name, QTH, WX, power, antenna etc.).

II.9.27. CW training software

- UBA CW course on the UBA-website (www.uba.be)
- G4FON Koch method trainer (www.g4fon.net)
- Just learn Morse code (www.justlearnmorsecode.com)
- Contest simulation (www.dxatlas.com/MorseRunner)
- Increase your speed using RUFZ (www.rufzxp.net)
- etc.

A few important hints:

- Never learn CW by counting *DITs* and *DAHs*...
- Never learn CW by grouping together similar characters (e.g. e, i, s, h, 5): this will make you count *DITs* and *DAHs* forever!
- Never describe the CW code for a character using the words *dot* and *dash* but rather using the words ***DIT*** and ***DAH***. *Dots* and *dashes* make us think of something visual, *DITs* and *DAHs* make us rather think of sounds.

II.9.28. Most used CW abbreviations

AGN:	again
ANT:	antenna
AR:	end of message (prosign)
AS:	wait a second, hold on (prosign)
B4:	before
BK:	break
BTW:	by the way
CFM:	(I) confirm
CL:	call
CL:	closing (down) (prosign)
CQ:	general call to any other station
CU:	see you
CUL:	see you later
CPI:	copy
CPY:	copy
DE:	from (e.g. W1ZZZ de G3ZZZ)
DWN:	down
ES:	and
FB:	fine business (good, excellent)
FER:	for

GA:	go ahead
GA:	good afternoon
GD:	good
GD:	good day
GE:	good evening
GL:	good luck
GM:	good morning
GN:	good night
GUD:	good
HI:	laughter in CW
HNY:	Happy New Year
HR:	here
HW:	how (e.g. HW CPY)
K:	over to you
KN:	over to you only, go ahead please and others keep out
LP:	long path (propagation)
LSN:	listen
MX:	Merry Christmas
N:	no (negation)
NR:	number
NR:	near
NW:	now
OM:	old man (male ham)
OP:	operator
OPR:	operator
PSE:	please
PWR:	power
R:	roger, yes, I confirm, received
RCVR:	receiver
RX:	receiver
RIG:	equipment
RPT:	repeat
RPRT:	report
SK:	end of contact (prosign)
SK:	silent key, a deceased ham
SP:	short path (propagation)
SRI:	sorry, excuse me
TMW:	tomorrow
TMRW:	tomorrow
TKS:	thanks
TNX:	thanks
TRX:	transceiver
TU:	thank you
TX:	transmitter
UFB:	ultra fine business
UR:	your
VY:	very
WX:	weather

XMAS:	Christmas
XYL:	wife, spouse, ex-young lady
YL:	young lady
YR:	year
51 and 55	is CB slang. Do not use it.
73:	best regards 73 is also commonly used in phone: never say or write *73s*, *best 73* or *best 73s*; all of these are corruptions. Say *seventy three* and NOT *seventy three**s***.
88:	love and kisses. Same remarks as for '73'.

SUMMARY (most important Q codes and prosigns)

- **AR:** *end of transmission*: indicates the end of a transmission which is not addressed to anyone in particular (e.g. at the end of a CQ)
- **K:** *over to you*: ends a transmission of a conversation between 2 or more stations.
- **KN:** *over to you only*: similar to 'K' but you emphasize you do not want to hear any other callers or breakers.
- **SK:** *end of QSO*: is used to end a QSO (SK = Stop Keying).
- **CL:** *closing down station*: last code sent before closing down your station (CL = closing down)
- **QRL?:** *is the frequency in use?*: you must always use it before calling CQ on a new frequency.
- **QRZ?:** *who called me?*: QRZ has **no** other meaning.
- **QRS:** *reduce your sending speed*
- **AS:** *just a moment, hold on…*
- **= :** *I am thinking, hold on, uh…* (also used as a separator between portions of text)

II.10. OTHER MODES

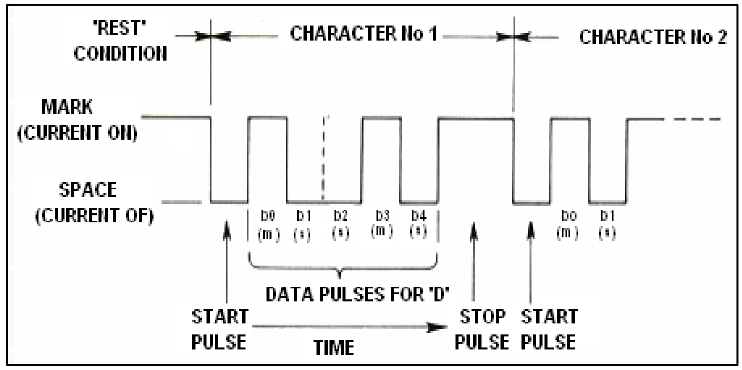
So far we have discussed operational behavior for phone and CW operating in great detail, as these are by far the most frequently used modes in amateur radio. You will have noticed that general operational behavior is very similar in both modes, and differences are mainly due to the use of the Q code, prosigns and other specific terminologies.

The basic procedures as outlined for phone and CW apply to most of the other frequently used modes, such as RTTY, PSK(31), SSTV etc.

Radio amateurs also use highly specialized modes such as Fax, Hell (schreiber), contacts through satellites, EME (moonbounce, Earth Moon Earth), meteor scatter, Aurora, ATV (wideband amateur television), etc., which, to a certain extent, may call for specific operational procedures.

In the next few pages we will cover some of these *other* modes.

II.10.1. RTTY (Radioteletype)



II.10.1.1. What is RTTY?

- RTTY is the oldest of the digital modes used by hams, if you exclude CW, which really is also a digital mode. RTTY is used to send and receive text. The code used in RTTY was developed to be generated and decoded by a machine. In the old days (the days of *Telex* machines), these were mechanical machines that generated and decoded the *Baudot* code, which is the original teleprinting code invented in 1870! Each character typed on the machine keyboard is converted to a 5 bit code, preceded by a start bit and followed by a stop bit. With 5 bits one can, however, only obtain 32 possible combinations (2^5 = 2x2x2x2x2). As we have 26 letters (in RTTY only uppercase letters are available) plus 10 figures and a number of signs, the Baudot code has given 2 different significations for each 5 bit code, which depend on the state the RTTY machine is in. These states are the so-called *LETTERS* and *FIGURES* states. If the machine is sending letters, and needs to send figures, it will first send a 5 bit code corresponding to *FIGURES*. This code will set the machine (or software) in the *FIGURES* state. If this code is not received, the following figures will be printed as (the equivalent code) letters. This is a frequently occurring error that all RTTY operators are well acquainted with, e.g. while receiving the RST report (*599* is received as *TOO*). Nowadays, RTTY is almost exclusively generated using a PC with sound card, using dedicated software.
- On the amateur bands the Baudot code is transmitted by FSK (<u>F</u>requency <u>S</u>hift <u>K</u>eying). The transmitter carrier is shifted 170 Hz between on and off (called **mark** and **space** in RTTY). In the early days of RTTY the shift was 850 Hz. The Baudot code does not contain any error correcting mechanism. The standard speed used on the amateur bands is 45 Baud. Using a 170 Hz shift, the –6dB bandwidth of the FSK signal is approximately 250 Hz.
- As RTTY is simply the shifting of a (constant) carrier, the *duty cycle* of the transmitted signal is 100% (versus approximately 50% in CW and 30 to 60 % in SSB depending on the degree of speech processing). This means that we shall never push a 100 W transmitter (100 W in SSB or CW) over 50 W output in RTTY (for transmissions lasting longer than a few seconds).

II.10.1.2. RTTY frequencies

- Before 2005, IARU subdivided the various ham bands *by modes* (phone band, CW band, RTTY band etc.). As the Band Plan since 2005 is based on *transmitted signal bandwidth* rather than mode, the Band Plan can be quite confusing for newcomers and old timers alike.
- We therefore have listed the range of frequencies which are most frequently used for each mode. These frequencies may be slightly different from what you find in the IARU Band Plan in as far as we can compare modes with bandwidth, which is not always obvious. The table below is not meant to replace the IARU

Band Plan.

160m:	1.838 – 1.840 kHz.	Very little RTTY on 160m. Stay with the entire signal in this window USA: 1.800 – 1.810 kHz (not allowed in Europe)
80m:	3.580 - 3.600 kHz	Japan: 3.525 kHz
40m:	7.035 - 7.043 kHz	
30m:	10.140 - 10.150 kHz	
20m:	14.080 - 14.099 kHz	
17m:	18.095 - 18.105 kHz	
15m:	21.080 - 21.110 kHz	
12m:	24.915 - 24.929 kHz	
10m:	28.080 - 28.150 kHz	

II.10.1.3. Specific operational procedures

- All standard phone and CW procedures apply.
- RTTY is extremely sensitive to QRM (all kinds of interferences). Pileups must be run in the split frequency mode (see § III.1).
- The Q codes were originally developed for use in CW. Later, hams started using a number of these codes in phone, where they have been widely accepted. One can of course also use these Q codes in the newer digital modes such as RTTY and PSK (See § II.10.2) rather than to develop another set of codes of their own, which would inevitably lead to confusion.
- In the digital modes all computer programs provide the facility to create files with short pre packaged *standard* messages that can be used in a QSO. An example is the so-called *brag tape* that sends endless information about your station and your PC. Please do not send all these details unless your correspondent asks for it. A brief 'TX 100 W, and dipole' will be sufficient in most cases. Just give information your correspondent could be interested in. Don't end your QSO by sending the time, the number of the QSO in your log etc. This is worthless information. Your correspondent also has a clock and he does not care how many QSOs you have already made. Respect your correspondent's choice, and don't force him/here to read all that garbage.

Typical RTTY QSO:

QRL? DE PA0ZZZ

QRL? DE PA0ZZZ

CQ CQ DE PA0ZZZ PA0ZZZ PA0ZZZ AR

PA0ZZZ DE G6YYY G6YYY K

G6YYY DE PA0ZZZ GA (good afternoon) OM TKS FER CALL UR RST 599 599 NAME BOB BOB QTH ROTTERDAM ROTTERDAM HW CPI? G6YYY DE PA0ZZZ K

PA0ZZZ DE G6YYY GA BOB UR RST 599 599 NAME JOHN JOHN QTH LEEDS LEES PA0ZZZ DE G6YYY K

G6YYY DE PA0ZZZ TKS RPRT JOHN STN 100 W ANT 3 EL YAGI AT 18M WX RAIN PSE QSL MY QSL VIA BUREAU 73 AND CUL G6YYY DE PA0ZZZ K

PA0ZZZ DE G6YYY ALL OK BOB QSL VIA BUREAU 73 AND TKS QSO PA0ZZZ DE G6YYY SK

73 G6YYY DE PA0ZZZ SK

II.10.1.4. Nominal transmit frequency on RTTY

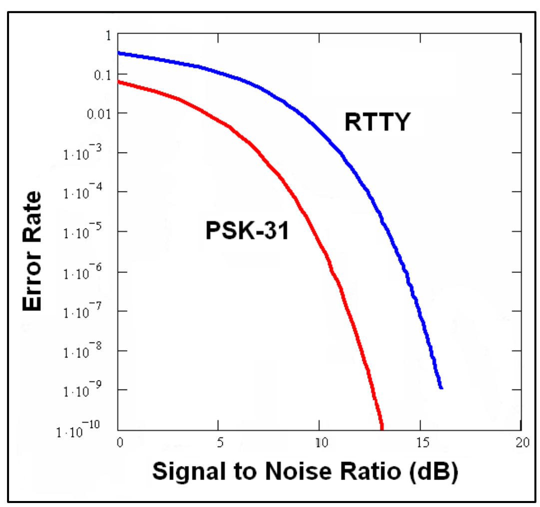
- Two definitions were made long time ago:
  1. The frequency of the **mark signal** determines the **nominal frequency** of an RTTY signal.
  2. The **mark signal** must always be **transmitted** on the **highest frequency**.
- If we listen to an RTTY signal, how can we tell which of the 2 tones is the mark signal? If you receive the signal on USB (upper sideband), the mark signal is the signal that has the higher audio tone. In LSB it is, obviously, the other way around.
- RTTY usually employs one of three methods to be generated in a transmitter:
  1. **FSK** (Frequency Shift Keying): the carrier is shifted according to modulation (mark or space). RTTY is actually FM. All modern transceivers have an FSK position on the mode selector switch. These transceivers all indicate the correct frequency on the digital display (being the mark frequency), provided that the modulating signal (the Baudot code) is of the correct polarity. You can usually invert the logic polarity either in your RTTY program or on your transceiver, or both (positions *normal* and *reverse*). If not set correctly, you will be transmitting *upside down.*
  2. **AFSK** (Audio Frequency Shift Keying): in this method the Baudot code modulates a generator which produces two audio tones, one for mark and one for space. These audio tones must fall within the audio passband of the transmitter. Modern RTTY programs on a PC generate these two tones using the soundcard. These tones serve to modulate the transmitter in SSB.
     a. on **USB**: in this method the transmitter, in upper sideband position, is modulated by the AFSK audio tones. Assume you transmit on 14090 kHz (zero beat frequency or suppressed carrier frequency on SSB). If you modulate your transmitter with two audio tones being e.g. 2.295 Hz for mark and 2.125 Hz for space, the mark signal will be transmitted on **14.092,295 kHz** and the space signal on 14.092,125 kHz. This agrees with the definition given above (mark → highest frequency). Watch out, your transmitter will indicate 14.090 kHz on its dial! In other words, if properly modulated (tones not inverted) and when using 2.125 Hz (space) and 2.295 Hz (mark) as modulation tones, **you simply add 2.295 Hz to the SSB dial reading** (the nominal SSB frequency) of your transceiver to obtain the nominal RTTY frequency.
     b. on **LSB**: same as above but transmitted in LSB. Here, the two transmitted frequencies will be below the suppressed carrier frequency. If

we use the same frequencies for the mark and space tones as for USB (mark = 2.295 Hz and space = 2.125 Hz), the **mark signal** will now be on 14.090 – 2.295 = **14.087,705 kHz** and the space signal on 14.087,875 kHz. This does **not** meet the definition that the mark signal always is the signal with the highest frequency. Therefore, we have to invert the modulating audio tones on LSB. Note that here too the transmitter dial will indicate 14.090 kHz! In this case (now 2.125 Hz is the mark frequency and 2.295 Hz the space frequency) we shall **subtract the frequency of the mark tone** from the nominal SSB frequency (shown on the dial of the transceiver) to obtain the nominal RTTY frequency. Using the same example: 14.090 kHz – 2,125 kHz = **14.087,875 kHz**.

- Why is it so important to know the correct nominal frequency? Assuming you'd like to spot an RTTY station on a DX Cluster, it is better to give the correct frequency and not something that may be a couple of kHz off.
- Another reason is the need to stay within the frequency ranges of the IARU Band Plan for RTTY. Example: according to the Band Plan 14.099 - 14.101 is reserved for beacons (e.g. the NCDXF beacon network). This means that if you use AFSK with 2.125 (space) and 2.295 Hz (mark) as modulating tones in USB, you should never transmit with a **dial reading** on your transmitter higher than 14.099,000 – 2.295 = 14,096.705 kHz. Taking into account the effect of the sidebands, it is safe to round off this figure to 14,096.5 kHz.
- Why do we use such high frequencies (2.125 and 2.295 Hz) for the AFSK generator? To achieve extra attenuation of any harmonics of these audio signals, by having all harmonics fall outside the SSB filter passband.
- If at all possible, use your transmitter in FSK rather than AFSK to generate RTTY signals. In most cases the quality of signals generated in FSK is far superior.

II.10.2. PSK 31 (Phase Shift Keying)

II.10.2.1. What is PSK31?



- PSK31 is a digital mode, designed for keyboard-to-keyboard communications via radio. This mode uses the soundcard in your computer to convert your typewritten messages into a modulated audio signal, and to convert received PSK-31 audio signals into text.
- The PSK31 signal, operating at 31,25 bauds (which is ample for hand typed messages), has, theoretically, an extremely narrow bandwidth of 31 Hz at – 6dB (in practice bandwidth is approx. 80 Hz). PSK31 does not include an error correcting algorithm. But for S/N ratios greater than 10 dB, PSK31 is virtually error free. At lower S/N ratio's, PSK31 is approximately 5 times better than RTTY.
- Each of the characters of the Baudot code, used in RTTY, uses a binary code

composed of a fixed number of 5 bits, which means that the length of each of those is the same. PSK31 however uses a ***varicode***, which means a code of **variable length**. Example: The letter ‘q’ is coded by not less than 9 bits (‘**110111111**’) , while the letter ‘e’ only contains 2 bits (‘**11**’). On average a character contains 6.15 bits. Most lowercase PSK31 characters have fewer bits in them than their upper-case equivalents, so it takes less time to transmit lower-case characters.

- Unlike RTTY, the transmission of PSK31 signals does not use a start or a stop bit. Instead of using two frequencies to transmit the code, as is done in RTTY (using FSK), PSK31 uses a single frequency, of which the phase is changed (by 180°) to transmit logic states 1 and 0.

II.10.2.2. PSK31 frequencies

The table below does not replace the IARU Band Plan, but gives a picture of the various band segments as they are actually being used in PSK31:

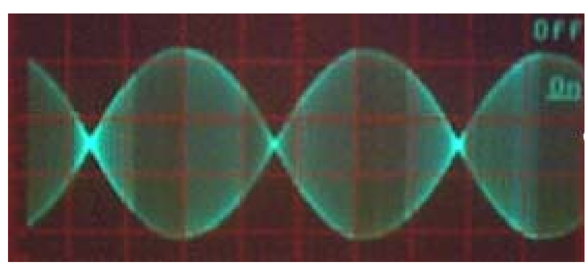
160m: 1.838 - 1.840 kHz
80m: 3.580 - 3.585 kHz
40m: 7.035 – 7.037 kHz (7.080 in Region 2)
30m: 10.140 - 10.150 kHz
20m: 14.070 - 14.075 kHz
17m: 18.100 - 18.102 kHz
15m: 21.070 - 21.080 kHz
12m: 24.920 - 24.925 kHz
10m: 28.070 - 28.080 kHz

II.10.2.3. Adjusting the transmitter for PSK31

PSK31 is a popular digital mode where excellent results can be obtained using fairly low power and simple antennas. Its intrinsic bandwidth is very small, but it is very easy to overmodulate the transmitter, resulting in a very wide signal. Therefore it is very important to adjust the equipment correctly.

A few guidelines:

- Keep audio processing and/or speech processing switched off *at all times*.
- Set the transceiver in USB mode (LSB is also possible, but normally USB is used).
- Run as little power as necessary to have a solid QSO.
- Use an oscilloscope to monitor the waveform of your transmitted signal. The picture shows the waveform of a well adjusted PSK31 signal, which resembles the waveform of a two-tone test, used for measuring PEP power in SSB.

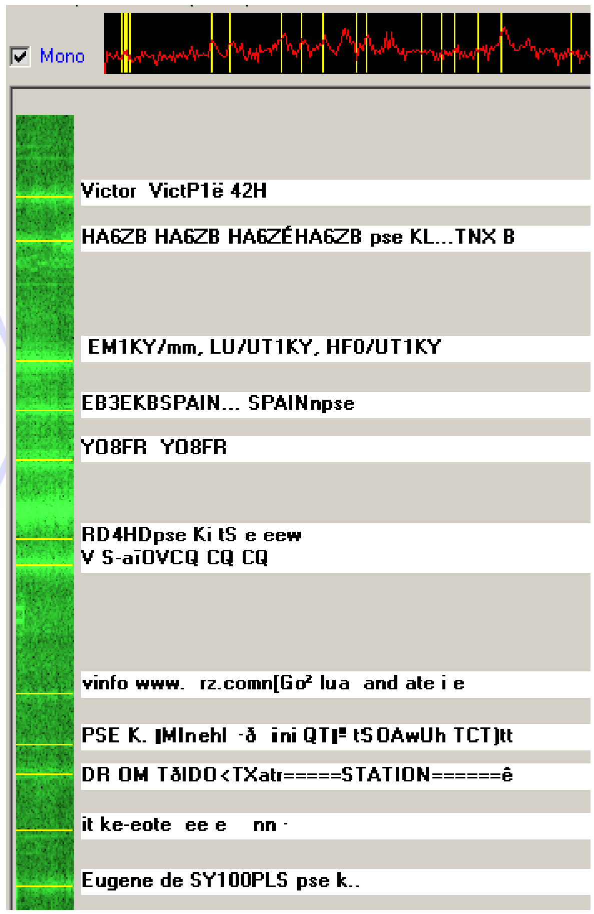


- When running 100W PEP, the power meter of the transmitter will indicate 50 W, provided the transmitter is not overmodulated. A 100 W transmitter can be run at 100 W PEP (not average!) for long periods of time (the wattmeter indicating 50 W). The *duty cycle* is 50%.
- Small dedicated test equipment is now also available for monitoring the quality of the outgoing signal, e.g. the PSKMETER by KF6VSG

(www.ssiserver.com/info/pskmeter/) or the IMDmeter by KK7UQ (kk7uq.com/html/imdmeter.html). The use of such equipment or an oscilloscope is highly recommended.

II.10.2.4. Receiving PSK31 signals

- Some software makes it possible to decode dozens of PSK31 signals simultaneously. With such software you can monitor a whole chunk of the spectrum if you use a relatively wide filter in the receiver (e.g. 2,7 kHz). The waterfall spectrum shows all of the signals in that passband and all of these are being decoded on the screen. This is the ideal way of operating in **monitoring** mode or when you go ***search and pounce*** (hopping back and forth between stations on the band).
- If you want to really dig in the noise or just work stations on one and the same frequency, the narrowest filter in your receiver (e.g. 200 Hz) will give you improved performance (better signal to noise ratio, no reduction of receiver sensitivity due to AGC action triggered by strong adjacent stations within the receive passband, less chance of intermodulation etc.). In this case the waterfall display will only show you one station.



II.10.2.5. Nominal PSK31 frequency

- If you operate in the wide bandwidth mode with e.g. 2,7 kHz bandwidth, the easiest is to set your transceiver precisely at a *round figure* frequency, e.g. 14.070,000 kHz. When you select a station on the waterfall display (you usually have to click on it), the software will show the nominal audio frequency of the station you selected, e.g. 1.361 Hz. In that case, and assuming you work on USB, the transmit frequency of that station is 14.070,000 kHz + 1.361 Hz = 14.071,361 kHz.

II.10.2.6. The RSQ Report System

The traditional RST signal report is not really suitable to be applied meaningfully to the digital modes such as PSK31, causing the majority of operators to give contest style 599 reports regardless of the true merit of the received communication. RSQ (Readability, Strength, Quality) has been adapted from RST to provide a more meaningful signal report for HF digital modes.

- **RSQ Readability:** the descriptive table (shown below) has a corresponding range of percentage readable text. This is consistent with the common practice of providing a percentage figure during a QSO.

- **RSQ Strength:** most HF digital mode programs provide a broadband waterfall or spectrum display. Hence a visible measure of signal trace relative to noise is more meaningful than an S-meter reading that averages the strength of all signals in the pass band.
- **RSQ Quality:** the presence of additional unwanted trace modulation observed on the waterfall or spectrum display indicates possible spurious emissions (mainly caused by overmodulation) and provides a sound basis for assessing the quality of digital mode signals.

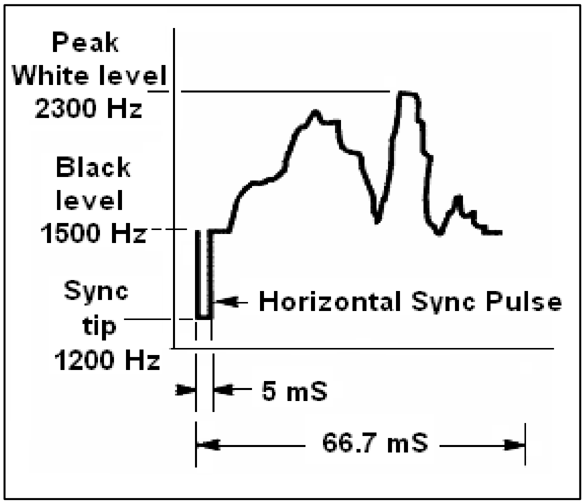
Readability	**R5**	> 95% perfectly readable
	R4	80 % practically no difficulty, occasional missed characters
	R3	40 % considerable difficulty, many missed characters
	R2	20 % occasional words distinguishable
	R1	0 % undecipherable
Strength	**S9**	Very strong trace
	S7	Strong trace
	S5	Moderate trace
	S3	Weak trace
	S1	Barely perceptible trace
Quality	**Q5**	Clean signal – no visible unwanted sidebar pairs
	Q4	One barely visible pair
	Q3	One easily visible pair
	Q2	Multiple visible pairs
	Q1	Splatter over much of the spectrum

(Source: http://www.rsq-info.net/)

II.10.3. SLOW SCAN TV (SSTV)

II.10.3.1. What is SSTV?

- Slow Scan TV is a picture transmission mode, capable of transmitting and receiving static pictures via radio. It is **Narrowband Television**. Broadcast quality TV requires a bandwidth of 5 to 10 MHz and transmits 25 or 30 pictures per second. The maximum bandwidth of SSTV is approx. 2,7 kHz (the bandwidth of an SSB signal). Black is represented by a 1.500 Hz tone and white by a 2.300 Hz tone together with a sync pulse at 1.200 Hz, well below the black level so it is invisible. The sync pulses that are sent at the end of each line are 5ms in length and at the end of each frame 30ms in length.



- SSTV is **not** a digital mode like RTTY and PSK31. It is an analogue mode like SSB. It uses frequency modulation, whereby every different value of brightness

of a spot in the image is represented by a different audio frequency. Color is achieved by sending the brightness of each color component (usually red, green and blue) separately and sequentially. On HF this audio signal is then fed into an SSB transmitter. On VHF, FM modulation is also used. There are 27 different modes of transmission (sometimes called *protocols*), the most popular ones being Scottie One and Martin One. Most software will handle the different modes.

- Nowadays PCs are widely used as SSTV decoders/generators. The SSTV program generates the signal to be transmitted using the soundcard, while on reception the sound of the SSTV signal will be converted in the same soundcard into the digital data to generate a picture through the SSTV software program.
- As SSTV is the transmission of a continuous tone of varying frequency and constant amplitude, it means that the *duty cycle* is 100%. For most commercial transmitters, it means that you will have to run maximum 50% of the peak power the transmitter can run in SSB, just like in RTTY.

II.10.3.2. SSTV frequencies

The table below does not replace the IARU Band Plan, but gives an overview of the various band segments as they are actually being used in SSTV:

80m:	3.735 +/- 5 kHz in LSB
40m:	7.035 – 7.050 kHz in LSB
30m:	very little SSTV (narrow band)
20m:	14.220 -14.235 kHz in USB
17m:	very little SSTV (narrow band)
15m:	21330 - 21.346 kHz in USB
12m:	very little SSTV (narrow band)
10m:	28.670 - 28.690 in USB

II.10.3.3. Operating SSTV

To stay within the limits of the rules and good behavior, we should only transmit images related to our hobby (test pictures, schematics, sketches, as well as pictures of equipment, the station, the operator, the antennas, etc.) or very neutral pictures (landscapes, flowers, QSL card). More generally, the content of the images sent should meet the rules as explained in § II.7.

If you are interested in SSTV, start by spending a lot of time monitoring the SSTV frequencies and testing the available software.

A few operational hints:

- prior to making any CQ call, listen for a while to make sure the frequency you intend to use is clear,
- next, ask a few times ‘is this frequency in use?’. If there is no reply, make your CQ call;
- it’s a good idea always to precede pictures with a phone CQ (‘CQ SSTV, this is…’);
- always announce the mode (protocol) of transmission before sending a picture;

- do not break in on a QSO by sending a picture. Use SSB to do so;
- never send a picture to another station without his invitation or OK to do so;
- never transmit a series of pictures one after the other without any reasonable pause. The object of SSTV is to make a QSO and not to put on a slide show;
- always ask the station you want to work if he is ready to copy your picture;
- DX stations often work from a list, which they have taken previously on the frequency;

- it is nice to show both your call and the call of the station you are working on the image you are sending;
- try to use images with plenty of contrast, and if text is part of it, show it in large, bold letters.

II.10.3.4. The RSV report used in SSTV

- In SSTV we do not exchange an RS report (phone) nor an RST report (CW), but an **RSV**-report where V stands for **V**ideo and reports the Image Quality.
- R stands for readability (1 to 5) and S for Strength (1 to 9), as used on phone and on CW.

V = 1	heavy QRM and image deformation, parts of image indiscernible
V = 2	heavily distorted image, callsign barely readable
V = 3	average quality image
V = 4	good image, little deformation, little interference
V = 5	perfect image

III. ADVANCED OPERATING

III.1. PILEUPS

- Chances are that sooner or later you will be hit by the DX bug, if you have not been yet. In that case you will inevitably be confronted with pileups.

III.1.1. Simplex pileup

- Both the DX station and the callers are on one and the same frequency.
- The main merit of this method is that it is space conservative (only one frequency being used).
- It is an inefficient method of operating when *many* stations are calling. Depending on the expertise of the DX station, *many* can mean as few as 5 stations. Under such circumstances the QSO rate will be slow.
- What starts as a simplex pileup often evolves into a split pileup.

III.1.2. Split (frequency) pileup

- Most QSOs are made when both stations transmit on exactly the same frequency.
- When the DX station is confronted by an ever growing simplex pileup, his QSO rate will likely go down for one or more of the following reasons:

  - interference from stations calling one on top of the other;
  - the callers will have difficulty copying the DX station because some (many) of them call while the DX station is transmitting;
  - more and more stations don't hear or do not follow the instructions given by the DX station;
- In order to be heard by the callers, the DX station operator will move the pileup: he will listen on a frequency away from his transmit frequency (often 5 kHz or more). The net result is that the calling stations no longer interfere with the DX station's transmissions, as they are now on separate frequencies.
- The problem however remains that the DX station still has to listen to the *single frequency* pileup in order to pick out stations one by one.
- To maximize his chances of doing so, he will spread out the pileup, and listen over a certain frequency range, e.g. '5 to 10 up'.
- This method of course uses more frequency spectrum than strictly necessary. The spread should be kept as small as possible, to leave room for other stations.
- Out of consideration for other spectrum users (other than those wanting to work the DX station) it is recommended only to use the split frequency method if the pileup has grown too large to be handled successfully using the *simplex* method.

III.1.3. How to behave in a pileup?

- Never call the DX station if you cannot copy him well enough.
- Make sure your station is properly adjusted before calling.
- Do **not** tune your transmitter on the frequency where the DX station is transmitting.
- Is the antenna in the right direction?
- Have you heard the instructions of the DX station? If not, wait and listen for instructions first!
- Listen.
- Listen.
- Listen and get acquainted with the **operating rhythm** of the DX station.
- If you hear frustrated hams making comments on the DX station's frequency: keep quiet and wait until the chaos has subsided.

Only if all these requirements are met, can you call the DX station!

III.1.4. Simplex pileup in phone

How do you *break* through a simplex pileup?

- Never call before an ongoing QSO is completely finished. This means: no tail-ending (see § III.2).
- **Correct timing** is the *key to success*. Do not start calling immediately, instead, wait until most of the noise on frequency has died down somewhat and chances

of getting through are increased. This is not a competition where you need to be the first and fastest caller! What is important is to call at the right moment. Wait a number of seconds until the most excited callers have stopped calling and the QRM has died down somewhat, before giving your call. This may be several seconds (5 to even 7 seconds).

- How should you call? Never give the call of the DX station you are calling; the DX station certainly knows his own call. Send your full call **just once**. Partial calls are **bad**. Not 'zulu zulu zulu' but 'golf three zulu zulu zulu'. Giving just part of your call creates confusion and lengthens the whole procedure.
- Yes, you will hear many stations giving only part of their call. It is bad practice and it is also illegal.
- Do not speak too fast nor too slowly, act normally (don't shout).
- **For spelling, use only the international spelling alphabet** (see attachment 1). No fantasies!
  - In radio traffic the phonetic alphabet (Alpha through Zulu), prescribed by the ITU, serves to avoid mistakes during exchanges of letters and words. To achieve this goal a **unique** phonetic word has been attributed to each letter of the alphabet. Note there is only one such series of words, and not one for each language!
  - A DX station listens for these unique words in the pileup cacophony. His ears are tortured by the chaotic presence of all these words (and figures) and fatigue increases. If we use other words than the standard words of the spelling alphabet, the procedure may become very inefficient because we're using words that the DX station does not expect to hear.
  - Far too often in pileups one can notice that the DX station missed just **that** letter that deviated from the standard alphabet, and consequently he has to ask for a repeat. Example: The spelling word 'Lima' cuts like a razor blade. Often we hear 'London' as an alternative. If your signal is very weak or interfered with, the DX station will probably understand 'Lima' but not 'London'!
  - Not only is the DX station listening for the exact words, he is also expecting certain consonants/sounds in these words and a defined number of syllables. If a syllable gets lost due to static (QRN) or QRM, he can often reconstruct the word by completing the missing consonants and/or number of syllables.
  - Only use **the correct English pronunciation** for the spelling words**.** Attachment 1 lists the phonetic pronunciation for each of these words. Of course, when you converse in your native language, which is different from English, you have a little more leeway.
- The DX station caught only a part of your call and says: '3ZZZ you're 59, QSL?'. This means: *the station with the call ending in 3ZZZ, you are 59, copy?*
- In your reply you should now emphasize the missing part of your call: 'this is _golf three, _ golf three zulu zulu zulu, 59 QSL?' (_ indicates a little extra pause).
- Normally the DX station should answer 'G3ZZZ thanks' whereby he confirms your call and ends the QSO. If he did not confirm the correction of your callsign, call again and ask: 'please confirm my call, G3ZZZ over'. Keep insisting for a confirmation, to avoid being incorrectly logged. If he does not confirm your call, there is no reason not to call him again, until you have heard

the DX station say your call correctly.

- If the DX station returns with an error in your callsign, repeat a few times the part of your call where the error occurred. Example: he says ‘G3ZZW 59’. Go back to him with: ‘this is G3ZZZ zulu zulu zulu G3ZZZ 59 over’. Normally he will then answer ‘G3ZZZ thanks’ or something similar. Make sure you have a confirmation of the correction as explained above.
- If the DX station returns with a partial call which does not resemble your call, or if he comes back to another station, then **keep quiet and listen.** If you keep calling it’s likely that one of the following scenarios will happen:
  - The DX station notices you are not following his instructions and you end up on his *black list*, which means you will not be able work him in the next few (many) minutes because of your *bad behaviour* (the DX station would love to work, but does not appreciate being willingly or unwillingly disturbed by you!).
  - Alternatively the DX station may call you and give you a RS ‘00’ report, by which you have been identified as an *offender* and displayed as such.
- If you keep calling out of turn while the DX station is trying to work another station, you are only causing QRM to that station, and you are slowing down the whole process. Not only will that station suffer from it, but eventually you will as well.
- If the DX station calls ‘1ABC **only**, you are 59, over’, this means he has a problem with undisciplined stations calling out of turn.
- Listen carefully to see if the DX station is not calling for particular geographic areas. ‘Japan only’ means that all stations from other countries but Japan should refrain from calling. **Keep quiet**, unless you are located in Japan.
- Perhaps he is calling *by numbers* (also sometimes called *by call areas*): ‘listening for sixes only’ means that only stations having a number 6 in their call are invited to call him. Others: **wait, keep quiet**.
- If you are a low power station (QRP), do not call as ‘G3ZZZ stroke QRP’. The DX station has problems enough with the pileup, he does not need the extra ballast from the ‘stroke QRP’. Don’t forget, in many countries using ‘stroke QRP’ as a call suffix, is illegal.
- When the DX station comes back to you with a report (‘G3ZZZ 59’), return with a short confirmation and report ‘thanks, 59 also’ (or ‘59 thanks’), and nothing else. There are many other stations waiting to make a QSO.

III.1.5. Simplex pileup in CW

- The general rules and procedures as explained above, obviously also apply to contacts on CW.
- Never call with ‘DE DL9ZZZ’. The word *DE* is superfluous and contains no information. The letters *DE* could also be the first 2 letters of a German callsign and lead to confusion.
- Never end your call with a ‘K’ at the end (K as invitation to send). This can cause confusion. If you send ‘K’ after your call (maybe after too short a space), the DX station may think that it is the last letter of your callsign. So: no ‘K’.
- Listen to the pileup to determine the sending speed you should use. Does the DX station work the slower or the faster stations? Don’t show off by sending too fast, like we sometimes hear. This is bound to be counter productive.

- In CW, '**KN**' at the end of a transmission means 'over to you only'. When the DX station sends: '...W1Z? KN' (or 'W1Z KN'), he wants to hear only the station with the callsign containing the characters *W1Z*. All others should stand by.
- If the DX station sends 'CQ NA' or 'QRZ NA', it means that he is looking for stations from North America only (NA = North America, SA = South America, AF = Africa, AS = Asia, PAC = Oceania /Pacific, EU = Europe, JA = Japan, USA = United States of America). So, follow the instructions.

III.1.6. Split frequency pileup in phone

If too many stations are calling on the DX station's frequency, the DX station will have to switch to **split frequency** operating, which will allow him to increase his QSO rate. How is this done? What do you need to know and to do, to be among the first ones to work the DX station in a split frequency pileup?

- Start by listening. Next, listen more!
- There are a few things you should know before you start calling:
  - Where is he listening? Is he listening on just one frequency or on a frequency range?
  - Is he listening for stations at random?
  - ... or for certain areas of the world?
  - ... or by numbers (the figure in your callsign)?
  - How does the DX station indicate where he is listening? He says e.g. 'up', 'down', 'up 5', 'down 10', 'listening between 200 and 210' etc.
- The better DX operator will indicate his listening frequency **after each QSO**; don't however expect this is always being done. If the pileup is very big, the DX station operator may think he can increase his QSO rate (gain 1 second every contact) by *not* telling the crowd after each QSO where he is listening. Not good practice though and it makes the people who just arrived on the scene, nervous. They have heard the DX station making a number of contacts without giving its call.
- Make sure you have well understood the listening range as specified.
- If he indicated a **specific area** he is listening for in which you are not located, relax, get yourself a drink, and listen!
- Maybe he is listening **by numbers**. If the number he specified does not match the number in your callsign, sit back and keep cool...
- If he specifies 'listening 14200 to 14225', it is almost like playing roulette unless you know where exactly he is listening. Therefore, keep listening and try finding out the exact frequency where the stations operate that he works. Most DX stations move slowly up and down in that range. Some just jump around like a kangaroo. In general, you will have the best chance to catch the DX station by calling slightly above or under the frequency where he worked his last station.
- Try to know as much as you can about the DX station's way of operating. Is he the kangaroo type or the slow moving type? The more you know about his *modus operandi*, the better your chances are to catch him quickly.
- Make sure you get the **rhythm** and the **pattern** of the DX station. A good DX station operator uses a fixed QSO pattern. Know the last words he sends before listening (usually either his call or 'thank you' or '5 UP' etc.).
- Before making any transmission, make sure all controls on your radio are set

correctly. Is your transceiver set for split frequency work, and is your transmit frequency set correctly? Double check!

- If you found where he made his last QSO, adapt your strategy to his operating pattern and give your call **just once** and listen.
- If he did not come back to you within 1 or 2 seconds, call again on the same frequency. Repeat this procedure until you hear the DX station coming back to someone (hopefully you!).
- If he comes back to another station, **stop calling** and start looking where that station is transmitting. It's a little bit like a cat and mouse game, only there is one big cat, and many little mice of which you are but one...
- Unfortunately you will always hear stations that keep endlessly throwing in their call even while the DX station is working someone. It often sounds like that's the way the majority of the stations do it. Reality is that, by doing so, these stations cause QRM and make progress much slower than what it could be with a little discipline.
- Operators who indulge in such procedures quickly make a non-enviable reputation for themselves. This procedure is the best guarantee for stations to be in there calling for a long time. It is clearly an example of how not to do it.
- Maybe the DX station operator will identify them as poor operators by replying to these offending perpetual callers and giving them an RS '00' report. Let's hope they understand what that means.

III.1.7. Split (frequency) pileup in CW

- In general the rules and procedures as explained for split operation in phone and for CW simplex remain applicable.
- How does the DX station indicate it is working split? At the end of each contact it will send e.g.: 'UP', 'DWN', 'UP 5' 'DWN 10', 'QSX 3515', 'UP 10/20'. A simple 'UP' or 'DWN' usually means that the DX station will listen 1 to 2 kHz up or down from its transmit frequency.
- It would be ideal to be able to transmit and listen at the same time, which we can approximate by operating **full break-in** (also called **QSK**). In full break-in we can listen between the *DITs* and *DAHs* of our own transmission. This means that we can hear the DX station the same split second he starts transmitting. Not all transmitters (and amplifiers) however, are equipped for QSK. You can also work **semi break-in** (*slower break-in*), in which the equipment switches from transmit to receive and vice versa between words or even letters. The delay time is usually adjustable to suit one's preference. Full break-in is an unmistakable advantage when calling in a split frequency pileup. It can help you avoid from inadvertently transmitting while the DX station is on the air. After all, we want to hear what the DX station is sending, don't we?

III.2. TAIL ENDING

- What is **tail ending**? A tail ender tries to outrun the competition by being *faster than his shadow*. He is listening to the station being worked by the DX station, and a split second before that station turns it over to the DX station, he throws in his call, usually half on top of that station. He is literally *stepping on its tail.*

- Strictly speaking, tail ending is even illegal as you are intentionally transmitting on top of another station, and hence causing interference to that station.
- In many cases it's not only the tail they step on, but more or less the entire beast.
- This operating procedure is not very polite but rather aggressive. The consensus is: don't do it.

THE ENDLESS CALLERS

Yes they exist, and there are many, many of them. They just want to work the new rare one, **whatever means it takes**. They do not have the slightest consideration for other stations. They transmit their call just as a continuous broadcast transmission, and hardly listen at all. Often one can hear the DX station coming back to them, two or three times, but to no avail. They don't hear the DX station because they (almost) never listen, and maybe because they have a typical 'alligator' station. Calling the DX station seems to be their hobby, not working the DX.

All of this would not be so bad and sad if, by this shameful practice, they did not cause a lot of QRM to other stations. What they do is pure and simple jamming.

This endless calling is an **ultimate proof of egoistic behavior**; shame on those who practice it.

III.3. DXPEDITIONS

- Many hams chase DX stations or chase *rare* countries or entities with hardly any ham population or any population at all.
- What counts for a *country* or better an ***entity***, has been established by the DXCC (DX Century Club), the organization which issues the much coveted DXCC award. See www.arrl.org/awards/dxcc/.
- Hams chasing DX try to work (= make a QSO with) a station operating from each one of these entities (almost 340 at present), and preferably on different bands and on different modes. This is the sport called **DXing** or **DX chasing**.
- To make it possible to work the rarest entities, hams organize expeditions to such rare spots. These are called **DXpeditions**. Larger DXpeditions are organized by groups of hams, sometimes comprising a dozen operators which will make the rare country available day and night and sometimes for weeks on end.
- The larger DXpeditions manage to make over 100,000 contacts in just one or 2 weeks! In most multi-operator DXpeditions multiple stations are simultaneously active on several of the amateur radio bands and modes.
- If you want to know about the DXpeditions that are currently active, and about the planned ones and the past ones, check ng3k.com/Misc/adxo.html.
- During DXpeditions it can be very crowded in certain portions of the (HF) ham bands. DXpeditions should always take into account other users of the bands,

and not invade major parts of the bands for an activity not all hams are involved in.

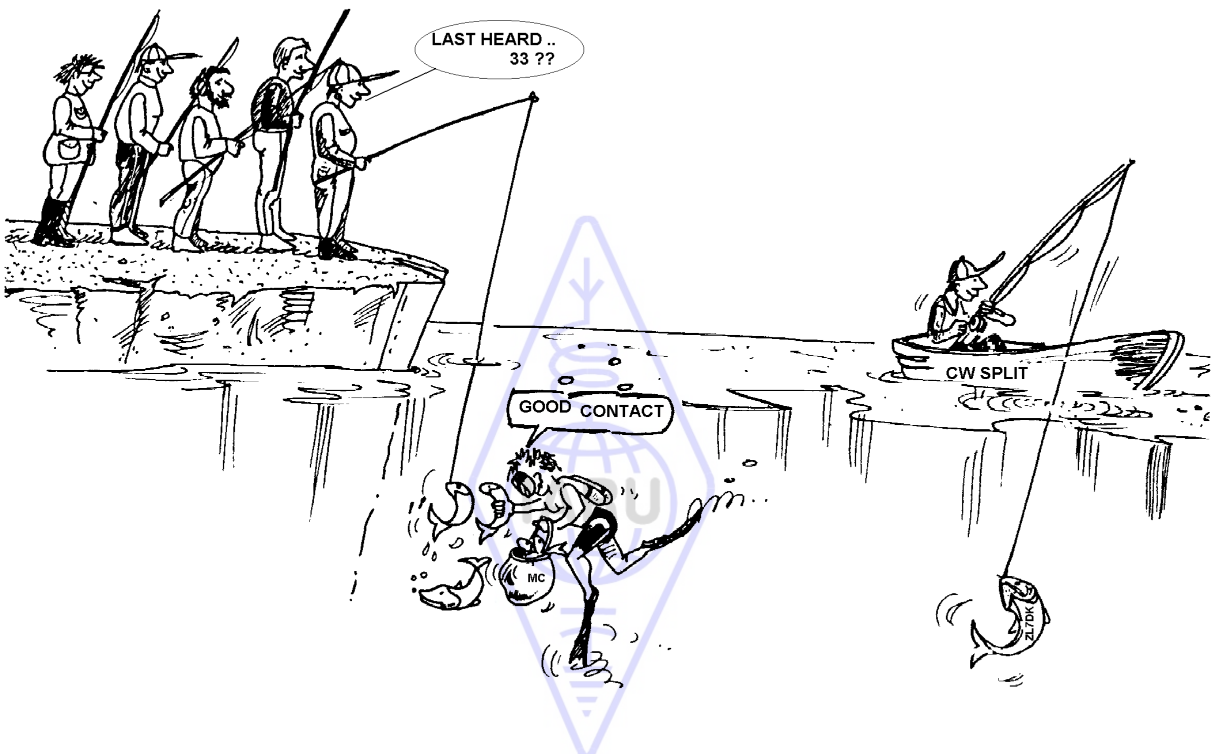
- Contacts with these DXpeditions are usually as short as contacts during a contest: only the call and a quick report are exchanged.
- Just about all contacts with DXpeditions are made in split mode
- The quality and the expertise of DXpedition operators are often judged by the amount of spectrum they require to work a split pileup.
- When important DXpeditions are active, a number of hams act like if they were called upon to complete a sacred mission to play *frequency cop*. Don't be tempted to become a frequency cop, we have too many of them already (see § III.10).
- Others, mainly frustrated minds, seem to enjoy making deliberate interference to such expeditions. They are simply making **deliberate QRM** (DQRM). If you witness this, do not react, just ignore it, they will go away if they have no audience to interact with. It is sometimes difficult to keep quiet but making comments only makes the chaos worse (see also § III.11). If you are sure you have identified one of these DQRMers, consider making a formal complaint to your licensing authorities.
- If you need any information about a DXpedition, do not ask for it on the DXpedition's frequency. Check the DXpedition's website or one of the *DX bulletins* where you can find all details: QSL address, operating frequencies, operators, and if applicable, the calls of possible *pilot station*(s).
- **Pilot stations** are the public relations managers as well as contact persons for a DXpedition. If you need to know something which you cannot find on the DXpedition's website, send an e-mail to the pilot station. He may be able to help you.
- Never ask on the DXpedition's frequency questions like 'QSL MGR?' or 'PSE SSB' or 'QSY 20M' etc. Better yet, don't ever transmit on their frequency (assuming we're talking split frequency operation)!

III.4. DX NETS

- Before the Internet was introduced to the ham community, a number of *DX Information Nets* were run on different amateur HF bands. Daily broadcasts gave information about recent as well as planned DX activities. For a number of years now, these nets have been replaced by different information systems, available via packet radio and the Internet.
- Besides these valuable DX nets, there is another form of DX net, aimed at *helping* stations to work DX. Working DX on DX nets, is like working DX in the *assisted category* (= with assistance).
- Many DX nets exist mainly to boost the ego of the net control operators.
- Here is how it usually works:
  - A net control station or *Master of Ceremony* calls for stations wanting to work a DX station who's waiting on the net's frequency.
  - In most cases, the MC will request stations to check in with only the last letters of their callsign, which is an illegal way of identifying in most countries. The MC makes a list of those callers. When the list is compiled, he will feed the stations one by one to the DX station. If a QSO is not

succeeding immediately, the MC will be glad to assist (from '...SS station, call again...' up to giving half of the report: '...you have the readability correct, but the signal strength is better than what you said...'). Often the MC is making half of the QSO... Not surprising that we sometimes hear comments like 'make one more guess...'.

- It is obvious that all of this has little to see with the **real sport** of DXing! Both serious DXers as well as experienced DX stations will stay away from such DX nets if at all possible.
- Such DX nets are not the place where you will learn the sport of DXing, neither learn how to improve your station nor your operating capabilities.



III.5. THE USE OF PARTIAL CALLS

- We have touched upon this subject before, and as it is such a bad habit and outspoken proof of poor operating practice, we come back to this subject:
  - In most DX-nets the callers are invited by the *MC* to call with only the last 2 letters of their call. It is ineffective and in addition illegal in most countries (you should always identify with the full callsign as received from the administration).
  - Net control stations use as an argument that they do not want to know the full callsign of the stations calling, so that they would not give it on the air whereby the DX station would copy the call via the control station. Noble thought, but it does not make sense.
  - The *MC* can ask the calling stations to check in correctly, which means by their full callsign. If the DX station at that time already copies the station checking in, the better for him.
  - If later in the procedure the *MC* calls the stations that have checked in, **he**

can call them by the last 2 letters of their call, which is quite legal. The rules say how you have to identify yourself, not how you call another station.
Example:

- The MC says: 'stations for ZK1DX, check in please'
- OH9ZZZ gives his (full) call: 'OH9ZZZ'
- If later in the procedure the MC calls OH9ZZZ, he simply says 'station with ZZ at the end of the call, make your call'
- OH9ZZZ now calls the DX station: 'this is OH9ZZZ, oscar hotel nine zulu zulu zulu calling ZK1DX, you are 55 over'
- etc.

It could not be simpler, and every step in this procedure is legal.

- Some have even started using this 2-letter procedure off the DX nets, e.g. in DX pileups.
- In addition to being illegal it is inefficient. Why?
  - Some simple mathematics will tell you: assume your call has 6 characters. If you only send 2 letters, the chance that at least part of your call will be copied is 3 times smaller than if you had given all 6 characters.
  - Your call is unique; two letters from your call are far from unique. This means that this procedure will often lead to confusion (several stations with those 2 letters calling simultaneously).
  - If the DX station copied your two letters (hopefully you're the only one using those 2 letters to call) he will still have to ask for the rest of your call. It is a pure waste of time. If he could copy two letters, there's a good chance he could have copied all 6 characters! All of this takes time, creates confusion and increases the chances of QRM.

Conclusion: never send just a part of your call. Are you ashamed of your call? Always send your full call, **be proud of it**! If, under whatever circumstances, someone asks you to identify by 2 letters of your call, identify by your full call and perhaps tell him you cannot do what he asks because it is illegal.

III.6. DX CLUSTERS

DX Clusters have largely replaced the local and international *DX information nets* of yesteryear.

III.6.1. Main Purpose

- Which DX stations are active *now* and on *which frequency*?
- DX Clusters are part of a global (worldwide) network, spreading *real time* information.
- It's a two-way system:
  - Spotting: entering interesting DX information to be used by others.
  - Using spots: you use DX information that's interesting for you.

III.6.2. Who do you spot?

- Rare DX-stations that are of interest to DX chasers. An example: ***14025 ZK1DX QSX UP5***.
- Do not send spots that have no added value. Do not spot *common* stations,

e.g. all stations from countries where there is plenty of activity such as W, F, G, ON etc., unless there is a good reason for it that makes your spot valuable. You can e.g. spot W6RJ on 160m from Europe, as we don't work W6's every day from Europe on 160m.

- Before spotting a DX station, first check if no one else has just spotted that same call.
- Watch out for typos! Wrong calls can sometimes be found in logs because the operator worked a station without even having heard its callsign, blindly having copied a busted (incorrect) call from the DX Cluster.

III.6.3. Which information is available, how to retrieve it

- **Activity info:** the DX spots. The spots come automatically on your screen in **chronological** order. You can retrieve **spots by band** (e.g. *sh/dx on 20m* gives you the last 10 spots on 20m , *sh/dx 25 on 20m* shows you the last 25 spots on 20m), **by call** (e.g. *sh/dx ZK1DX*, or *sh/dx ZK1DX 20*) or by **combination of band and call** (e.g. *sh/dx ZK1DX 20 on 15m*).
- **WWV** (see en.wikipedia.org/wiki/WWV_(radio_station))**, Solar Flux Index:** common commands are *sh/wwv* and *sh/wcy*.
- **QSL info:** on most DX Clusters you can retrieve QSL info using *SH/QSL cal*. If this function does not exist, type *SH/DX call 25*. Now you get the last 25 spots for that station, and chances are that one of the spots has the QSL info in the commentary field. A third possibility is to type *SH/DX call QSL*. This will list the last 10 spots for that station where the word *QSL* or *via* appears in the commentary field.
  - Some DX clusters may not have all of these commands, in which case you can find the QSL info via an Internet search engine.
  - It is not good practice to spot the station for which you need the QSL info by typing *QSL info please* in the commentary field. The purpose of this field is to provide additional useful information regarding the DX station. It is not the place to ask questions.
  - Depending on the DX Cluster's software, the abovementioned commands may vary somewhat. See your DX Cluster's help file.

III.6.4. A spot appears: a new country for you. What now?

- Do not start calling the DX station blindly.
- Make sure you copy the station well enough, verify if the spotted callsign is correct.
- Make sure you have heard the DX station's instructions before calling (his listening frequency, is he working *everybody* or working by numbers or by geographical areas?).
- Apply the guidelines as explained in § III.1. (Pileups). Good luck!

III.6.5. Things not to do on a DX Cluster

- **Self spotting**
  - What's that? It's a personal advertisement to the whole world, saying: *Here I am, on this frequency, please call me*.
  - It needs no explanation that this is just not done in Ham Radio. If you want to make QSOs, call CQ or reply to stations calling CQ.

- Self spotting leads to disqualification in contests.

- **Disguised self spotting**
  - An example: you work a nice DX station that came back to your CQ. When you finish your QSO you spot the call of the DX station, which was there but went off the frequency after finishing the contact. This spot has zero added value for the DX community, as the DX station is gone, but at the same time you attract a bunch of DXers to your frequency, hoping that this will help you work some other DX stations. This practice makes DXers nervous.

- **Bragging**
  - A spot is not for telling the world how great you are: don't spot a DX station (that's been spotted several times anyhow) with a remark: *I finally did it…*. In such a case you are not announcing the DX station, you're just bragging and telling the world how great you are… Modesty is a nice virtue.

- **Spotting a friend**
  - A good friend of yours is calling CQ repeatedly, without reply. You want to give him a little push and you spot him, though he is not at all a DX station. Don't do it. Neither your friend nor you will gain respect in the eyes of the ham community by doing so.

- **Asking a friend to spot you**
  - Is self spotting, using a cover up. Self spotting is not done, so do not you ask your buddy to spot you.

- **Being a cheerleader:**
  - Those who continuously spot their favorite contest station during a contest. It's like the supporters pushing bike racers during a race in the mountains. It isn't fair and it's unsportsmanlike.

- **Send a spot which actually is a private message**
  - We need to realize that each spot, each message on a DX Cluster is sent to many thousand of hams all around the world. DX Clusters have been connected through the internet for some years and your local DX Cluster is no longer local but part of a global network.
  - Unfortunately, some spots are private messages, like in this example: HA7xx sends a spot: *VK3IO on 1827*, with as comment *QRV???*, which obviously is not a spot but a private message (typed in the commentary field).
  - Another example: *UA0xxx spots ZL2yyy on 3.505 kHz* and adds *ur 339, my RST 449? Pse confirm*. This guy is making a fool of himself. His reputation amongst DXers is destroyed!

- **Using the DX Clusters as a worldwide chat channel**
  - With the **TALK** function you can send individual messages to another ham on your local DX Cluster. Some DX Clusters have a similar talk function where you can chat privately to a user on another DX Cluster, of course provided these clusters are linked (by e.g. a radio link or internet).
  - The **Announce Full** (**To All**) function is a totally different story. Any

message sent using this function will be sent to the users of all world wide linked clusters, and that may be many thousands at any given time. Be **very careful** when using this function. Most *To All* announcements are actually intended for one particular person, where 9,999 others are forced to read a message which is of no value to them. Example: a To All message from ON7xxx reads like *ON4xx, good morning Frans*. Another example, To All de DF0xx: *wir warten auf K3714*. Whatever that means. And there are, unfortunately, thousands more similar examples.

Do not ever use the *Announce Full* function as a chat channel. Also, never use this function to settle an argument or to insult someone. The world is watching you!

Only send messages that are of interest to a vast majority of the DXers. Example: you could announce that the DXpedition has just moved band, or frequency, or that they will be on such and such a frequency at such and such a time. Etc.

The general rule is: *To All* messages should indeed be of interest *to all*. If a message is not of interest to all (or a vast majority of them), don't send it via the *To All* function.

- **Using someone else's callsign on the DX Cluster**
  It appears that some disturbed minds check into a DX Cluster with other people's callsign, and do totally unacceptable things. This is even worse than anonymous transmissions, as in addition the call of an ignorant ham is being defamed.
  Never react on the DX Cluster if you are confronted with a similar situation.

III.7. DX WINDOWS

- The IARU Band Plan is a worldwide accepted *gentlemen's agreement* that 99 % of the radio amateurs adhere to.
- This Band Plan lists a couple of formal DX windows, where it has been agreed upon to give full priority to long distance work (DX contacts).

III.7.1. DX windows on the HF bands

- Presently there are three such windows in **IARU R1** (Europe, Africa and Middle East): **3.500-3.510 kHz** (CW), **3.775-3.800 kHz** (SSB) and **14.190-14.200** KHz (SSB). In **IARU R2** (North and South America) we count 7 windows: **1.830-1.840** kHz (CW), **1.840-1.850 kHz** (SSB), **3.500-3.510 kHz** (CW), **3.775-3.800 kHz** (SSB), **7.000-7.025 kHz** (CW), **7.175-7.200 kHz** (SSB) and **14.000–14.025 kHz** (CW) .
- The DX windows on 80m: in the middle of the day these frequencies can be used for *local* traffic, as there is no long distance propagation at that time. But we should be aware that even shortly after noon, local contacts in the DX windows of this band can cause problems to stations that are 1000 to 2000 km in the direction of the *terminator* (the line that separates the dark hemisphere from the lit hemisphere). Example: 13:00 UTC in Belgium in midwinter. It is 3 hours before sunset. At this time it is impossible to work DX from Belgium. But our signals can be heard with quite good strength in Scandinavia, only 1000 to

2000 km away, where sunset is several hours earlier. Although we do not hear DX stations at that time, we can very well cause QRM to other stations that are much closer to sunset. Conclusion: stay out of these windows at all times, unless you are trying to work DX yourself.

- When DXpeditions are active, these stations have full priority in using the abovementioned 20m DX window. Under those circumstances all other stations should clear these frequencies and do that in the true spirit of the IARU's gentlemen's agreement. This 20m DXpedition window was created in 2005, as a result of a continuous problem caused by an IT9-station.
- In addition to these *formal* windows, there are a number of *de facto* DX windows:
    - In SSB: 28.490-28.500, 21.290-21.300, 18.145, 14.190-14.200, 7.045 and 1.845 kHz
    - In CW: the first 5 kHz of each band, and also: 28.020-28.025, 24.895, 21.020-21.025, 18.075, 14.020-14.030 and 1.830-1.835 kHz
    - In RTTY: ± 28.080, ±21.080 and ± 14.080 kHz

  Avoid making local contacts in those windows. These are the frequency ranges where you can look for interesting DX stations.

III.7.2.c On VHF-UHF See the official IARU Band Plan: http://www.iaru.org/bandplans.html

III.8. SPECIFIC OPERATIONAL PROCEDURES FOR VHF AND HIGHER

- These are based on the same principles that apply to the HF bands.
- For QSOs via tropospheric propagation (local, or via temperature inversion) on the 50, 144 and 430 MHz bands, the procedures are exactly the same as on HF. The only difference is that often calling frequencies are used to initiate a contact. Once a contact is established, the stations will move to another frequency.
- QTH-locator: on VHF and higher, station locations are usually specified by using the QTH-locator, also called Maidenhead locator. The QTH-locator is a set of simplified coordinates (e.g. JO11) which allows the user to quickly judge the direction and the distance to the station he is working.
- There are specific operational procedures applicable to some very specific modes, mostly used on VHF and higher, such as:
    - Contacts via satellite.
    - EME QSOs (reflection via the moon).
    - Meteor scatter QSOs.
    - Aurora QSOs: reflection near the poles during Aurora.
    - ATV (wideband amateur television).
- It is outside the scope of this manual to enter into detail on these subjects. In all cases, operational behaviour remains based on the principles as explained in § I.2.

III.9. CONFLICT SITUATIONS

As explained in § I.2, the fact that we all (we're several hundred thousand hams in the world) *play* our hobby on one and the same field, the ether, will inevitably sometimes lead to conflicts. How do we handle these, that is the question!
Our behaviour on the bands should be based on **common sense, good manners** and **mutual respect**.

- Rule # 1: **never do or say what you would not want your best friend nor anyone else in the world to know about.**
- A problem is that radio transmissions can be made **anonymously.** A person making unidentified transmissions with malicious intentions is not worth being a radio amateur.
- Never ever contemplate **jamming** the transmissions from another station. As jamming can be done anonymously, it is the utmost expression of cowardliness.
- There simply is no excuse for such behavior, even if you think that the station deserves to be jammed.
- So, maybe there is a situation which in your opinion needs to be corrected? Perhaps rightfully so, but think twice what will be the **added value** to our hobby, to YOUR hobby, to your reputation, before you start doing or saying anything.
- Don't start **discussions** on the air. Chances are that others will join in and in no time what maybe started as a more or less friendly discussion, may degenerate. Keep personal conflicts off the air. Settle your arguments on the telephone, the Internet or in person.

III.10. COPS (FREQUENCY POLICE)

- Cops are self appointed would-be *frequency policemen* who think they need to correct other hams making an error, on the air and on the spot.
- Sometimes it is indeed necessary that a continuous *offender* (e.g. someone keeps calling on the transmit frequency of a DX station working split) gets told that he is causing a problem. But there are ways of telling…
- Time after time we note that the intervening cops cause a lot more havoc than the station they want to correct.

III.10.1. Types of 'cops'

- Most *cops* have good intentions and are not using foul language. They remain polite and are often successful in their attempt to keep the frequency of a DX station clear.
- Some *cops* also have good intentions but by using bad language and manners they don't achieve their goal to clear a frequency. These *cops* create chaos instead of calm.
- A third category consists of those using foul language with the objective of creating chaos. Their bad language and manners attract comments from colleague *cops*, with a resulting total chaos!

Do not react if you hear one of those would-be cops in action. Keep your distance and ignore them completely. This is the only way to make them stop.

III.10.2. What makes the cops appear?

- *Cops* mostly appear on a rare DX station/DXpedition's frequency, usually when this station is working in split mode.
- The trigger for their appearance is when an operator forgets to activate the split function on his transceiver and starts calling the DX station on its transmit frequency. This is the time for *cops* to start shooting/shouting.

III.10.3. The good sinners ...

- Quite a number of hams just don't know the proper way of operating under all possible circumstances. Not that they don't want to be good operators, but they just don't know how. They have to learn the trade by falling down and getting up. The reason is they were never taught. These are the ***good sinners***.
- ***Errare humanum est*** (*to err is human*): even so called experts make mistakes. No single human being is perfect. Everyone has on occasion transmitted on the wrong VFO (which means on the transmit frequency of a DX station working split). Maybe because we did not pay enough attention. Maybe we were tired or distracted; after all, we are only human.
- The first thing to consider in a situation where someone's error **needs** to be *corrected* is **how to pass the message**.
- When one gets called to order by a cop shouting 'up you idiot', it is sometimes difficult to refrain from answering on the spot 'have you never made a mistake, you arrogant cop?'.
- Don't however react in such a case, it will always be counterproductive.
- This is how chaos usually sets in.

III.10.4. ... and the bad sinners

- Some hams however seem to delight in using very poor operating habits. In this case ***Perseverare diabolicum*** (*to persist is devilish*) applies.
- There appear to be more and more *disturbed characters* that literally enjoy making life difficult for the well behaved operators. These are the sorts that try to disturb DXers with all means at their disposal. In some cases these are frustrated hams who, due to lack of knowledge and wisdom, are not successful in contacting the DX station, and who vent their frustration on their more successful colleagues.
- Sometimes we witness the most blatant use of vulgarity and obscenities from these characters.
- All they want is to make others react so that chaos erupts on the frequency.
- Some good advice: **never react** when you witness such an act. If nobody reacts, these characters will go away by lack of an audience (see also § III.11). If you are sure you have positively identified a station making this kind of **deliberate QRM**, consider making a formal complaint to your licensing authorities.
- Do not react either via the DX Cluster. Rest assured they are watching the DX Clusters as well.

III.10.5. Do you really want to be another cop?

- When you hear someone making a big or repetitive mistake, remember that you too have made errors in the past, haven't you? Be tolerant and forgiving!

- If you really need to say something (to correct a repetitive error), say it in a friendly and positive way, without insulting or sounding patronizing. If ON9XYZ by error repeatedly transmits on the wrong VFO, say '9xyz up please', not 'up you idiot'. The insult brings no added value to the message. It only tells us something about the person making the insult.
- Realize that your intervention may cause more interference than the actual error you try to correct!
- Before playing cop, think twice in which way your act will have a positive added value. If you still think it needs to be done, twist your tongue three times before going ahead.
- Always be polite and constructive.
- If you need to tell someone he's transmitting on the wrong VFO, always add a part of that station's call. How else can he know that your message is addressed to him? Say '9XYZ up please' not just 'up please' nor 'up up up up'.
- If you happen to be the 9xyz station, do not feel too embarrassed, *errare* only *humanum est*, and your apology will just cause more QRM.
- Don't forget that every cop, by acting as a cop, is doing something illegal: have you heard many frequency cops identifying as required?
- Another thought: one good cop can be a blessing, two cops are a crowd.

III.10.6. How to behave in the middle of a cop parade?

Being a DXer you will quickly grasp that you accomplish more by not reacting to cops at all. Try to swing something negative into something positive. Keep on **listening** (here's the magic word again) through the tumult to the DX station and in many cases you will be able to log the DX station while the cops are having a *jolly good time*.

III.11. TIPS FOR DX STATIONS AND DXPEDITION OPERATORS

Maybe sooner or later you will be operating at the other side of a pileup. Maybe you will be operator on a DXpedition, a dream of many hams. For the serious operator there are a number of guidelines and procedures to be applied as well, if he wants to be a successful operator. Here are a few tips:

- Give your callsign after **every** QSO. If you have a very long call (e.g. SV9/G3ZZZ/P), give it at least every few QSOs.
- If you work simplex and you cannot sort out the calls well enough (because too many stations call simultaneously on the same frequency), switch to split frequency mode and spread out the callers. Don't forget that, especially on the low bands where signals from far away DX stations can be very weak, you will be totally covered by the calling stations which are easily 50 dB stronger than you. For a rare DX station *split* is the way to operate.
- Before changing to split mode, check if the frequencies you want to use for listening are clear
- If you work split, mention it **after each QSO**. For example in CW: 'UP 5, UP5/10, QSX 1820' etc. In SSB: 'listening 5 up, listening 5 to 10 up, listening on 14237, up 5, down 12', etc.
- Do **not** give the split indication 'every now and then'. It may make the pile where you listen a little less dense, but inevitably creates havoc on your

transmit frequency and will make the split frequency band much wider than required. This is an unacceptable practice from all point of views.

- In CW split, listen **at least 2 kHz** above (or below) your transmit frequency, to avoid interference to your signal from key clicks generated by callers. A split of only 1 kHz, as is done regularly, is not enough.
- In SSB, this should be **at least 5, preferably 10 kHz**. Some signals of calling stations can be very wide and cause a lot of splatter on your transmit frequency.
- If, as a DX station, you operate split in the DX window of 80m (in Region 1: 3,5 – 3,51 MHz on CW or 3,775 – 3,8 MHz on phone), **listen for the pileup outside the DX window**. If you transmit e.g. on 3,795, listen below 3,775 MHz for the pileup (in CW above 3,51 MHz).
- Keep your listening window as narrow as possible to avoid interference to other band users.
- If in SSB you copied only part of a callsign, reply with that partial call plus a report, e.g. 'yankee oscar 59'. Do **not** say 'yankee oscar, again please'. Guaranteed this will attract a whole range of yankee oscars! If you have added a 59 report, you already made half of the QSO and there will be fewer disorderly callers.
- In CW, in a similar case, never send a question mark if you copied a partial call (e.g. 3TA). A question mark will trigger half of the pileup to start calling you. Send '3TA 599', and **not**: '?3TA 599'. Never send question marks in a pileup situation.
    - The following applies to all modes: if at first you copied only a partial call, always repeat the full call once you have it, so the station that called you is sure he worked you and can put you in his log. Example: assume you first copied a partial: '3TA'. Send '3TA 599' (in phone say '3TA 59'). He confirms: 'TU DE OH OH3TA 599' (in phone: 'oscar hotel, oscar hotel three tango alpha you're 59 QSL?'). If you now confirm with 'QSL TU' (in phone: 'QSL thank you'), there is no way OH3TA can tell you worked him. Therefore, confirm with: 'OH3TA TU' (in phone: 'OH3TA thanks').
- Once you returned to a partial call with a report, stick to that station, and do not let him be overpowered by other callers. You're the boss on the frequency, show it. You decide who gets in the log, no one else. The pileup can be quite undisciplined, but often this is due to a lack of authority from the operator of the DX station. If the crowd notices that you stick to the original partial call, and that their out of turn calling is to no avail, they will eventually give up, and show more discipline.
- If you give up on the original partial call and just pick up one of the loud undisciplined callers, you admit the wild callers are in charge of the frequency. Now you're in trouble. In many cases, chaos is a result of the DX operator not showing authority or not living by his own rules.
- If the partial call you originally came back to disappeared, do not just pick up the call of one of the strong undisciplined callers who's been giving you a hard time the last several minutes. Just call a CQ again and listen a few kHz higher or lower. **Never give the impression you are now calling one of the undisciplined callers**. Show them that their undisciplined calling was useless.

- You have returned for a particular station in the pileup (e.g. JA1ZZZ) and you have put him in the log. However he keeps calling you again, obviously because he did not hear you give him his report. Do **not** go back to him with 'JA1ZZ you are in the log' (on phone) or 'JA1ZZZ QSL' (CW) but **call him again and give his report again**. He obviously wants to hear his report!
- Always follow a **standard pattern** in your transmissions. Example (you are ZK1DX):

  ZK1DX 5 to 10 up → you hear ON4XYZ calling
  ON4XYZ 59 → you give his report
  QSL ZK1DX 5 to 10 up → you confirm, identify and call again
- If you keep following that same pattern, the pileup will know that when you say '5 to 10 up', you are listening again for new callers. Always maintain this same pattern, the same speed, the **same rhythm**. This way everyone will know exactly when to call. Should be like clockwork.
- If the pileup remains undisciplined, do not get too excited about it. If the situation does not improve, just move to another mode or band, but let the pileup know.
- Always stay cool, don't start insulting the pileup. All you can and must do is to firmly show the pileup that you are in charge, and that you set the rules. It is important that you emanate authority.
- Do not work so-called two-letter calls. If you hear such stations, tell them you want to hear 'full calls only'.
- If in split mode it appears that many of the calling stations are not copying you well, it is likely that your transmitting frequency suffers from interference. If this situation persists, in SSB try changing your transmit frequency 5 kHz, and tell the pileup about your move. In CW, moving 0.5 kHz will usually suffice.
- On CW, 40 WPM is about the maximum speed to be used during a smoothly ongoing pileup. On the lower HF bands (40-160m) it's better to use a little lower sending speed (20-30 WPM, depending on circumstances).
- Always keep the pileup abreast of your plans. When you go QRT, tell them. When you need a pit stop, tell them: 'QRX 5' ('QRX 5 minutes', 'standby'). If you move to another band, inform the crowd.
- If you want to keep the pileup calm and more or less disciplined, and keep your transmit frequency clear, the most effective way of doing so is to keep the callers happy. Let them know what you are doing. Know that they all (with one or two exceptions) want to work you. You are hot!
- The DX station operator sometimes works by numbers or call areas. This means that he will only reply to stations having the number he specified in their prefix. Statistically the pileup should be 10 times thinner!
- Avoid as much as possible working by numbers, it's not a very good system.
- If you want to apply this method, apply the following rules:
  - Once you started working by numbers, go through all numbers at least once. If you go QRT in the middle of a sequence, or start working random numbers all of a sudden in the middle of a numbering sequence, you are going to create commotion.
  - Never forget, when you work by numbers that 90% of the DXers are idling, biting their fingernails! They keep a close eye on you and carefully count

how many stations you work of each number, and you can be sure some operators will lose control if you do not soon reach *their* number.

- Always start a sequence with 0, and move up in numbers one by one. No frills. Keep it simple.
- Do not specify numbers at random: first 0's, then 5's, then 8's, then 1's etc... It will drive the pileup mad. If you follow a logical sequence, the pileup can more or less predict when it will be their turn. A random system will make them utterly nervous.
- Work maximum 10 stations of each number. Make sure you work approximately the same total of stations per number. If you manage to work 5 stations a minute, it will still take you 20 minutes to complete the circle. This means some stations will have to wait and sit idle for almost 20 minutes, which is a long time. On average the waiting time is 10 minutes. Don't forget propagation conditions can change a lot in 20 or even 10 minutes!
- Always tell the pileup how many stations you will work from each number and repeat that information every time you increment the number in the callsign.

• The method of calling by numbers is seldom used on CW.
• A better technique to make the pileup a little thinner is to work by continents or geographical areas. This also gives a better chance to remote regions of the world, where signals are often weak and openings shorter.
• In this case you will specify a continent, which means you insist that only stations from that area should call you. Example: if you want to work only North American stations, call 'CQ North America ONLY' or on CW: 'CQ NA'.
• Use this technique primarily to reach those areas of the world that have poor propagation or short openings to you.
• If you use this technique because the pileup is too dense, rotate quickly between the continents or areas. A good rule of thumb is that one should not stay with the same area for longer than 15 to max. 30 minutes.
• Inform the pileup of your plans, tell them exactly how you will rotate between areas, and follow your planning.
• Switch back to working all areas/continents as soon as conditions permit.
• Both abovementioned techniques should be avoided as much as possible, with one exception, where you look for difficult to reach areas.
• The main problem with these selective methods is that a large majority of hams is sitting idle, and getting nervous. Nervous DXers can easily change into aggressive cops. If you go QRT or change bands just before their number was supposed to come up, rest assured you will be called names on your transmit frequency.
• We have witnessed some DX operators trying to work by country. This must be avoided at all times for obvious reasons: now you have set 99% of the DXers wanting to work you, *on hold*. This way of operating guarantees chaos in no time.
• Watch out when using a preferential treatment for your friends or for stations from your home country. Do it very discretely and make sure it happens *invisibly.* Better yet, don't do it.
• So far we have listed a number of issues, all relating to operating procedures,

aiming at making chasing DX more enjoyable for the DX chasers and the DXpeditioners alike. It is evident that by education and training both groups can improve their operating and achieve a win-win situation for both: a better and more enjoyable DXing world.

- At one time or another almost all of us have been confronted with a situation where deliberate QRMers are out to destroy the fun enjoyed by thousands of DX chasers. They QRM the DX's transmit frequency either using no call or calls they 'borrow' for their unethical behavior. This issue is indeed an **ethical issue** (see § I.2.5), an issue of good and bad, and not an issue related to operating procedures. To a large extent this kind of QRM will not be changed by education and training.
- This D(eliberate)QRM is caused by a small group of social hooligans missing any degree of moral standards. Their acts are merely the expression of a steadily growing degree of selfishness we –unfortunately- seem to find nowadays in many layers of society.
- If you suffer from such DQRM, move frequency slightly, e.g. 500 Hz in CW, just sending your call followed by a string of DITS while slowly QSYing so the pileup understands what you are doing or, on phone, e.g. 5 kHz up or down after having announced your QSY. Don't mention the reason.
- Never acknowledge you are suffering from DQRM. The small numbers of individuals causing DQRM will most frequently stop acting if they have no audience, in other words if no one reacts to their provocation. Always ignore them; never quit.

LEGALLY BINDING?

Are all the procedures as outlined in this document legally binding? Most of them are not. A few examples: in most countries one should identify every 5 (in some 10) minutes. This rule exists for the monitoring stations and control authorities to be able to identify transmissions. These 5 minutes are a legal minimum, but good practice and sound customs as well as search for efficiency and good manners, in one word 'correct operating practice' tells us to also identify at each QSO, especially if these are short contacts as e.g. during a contest or when working a pileup. These operating procedures must make it possible for the entire amateur radio community to be able to enjoy the hobby in best understanding.

A similar example concerns the IARU Band Plan which has no binding legal character in most countries, but clearly serves at making living together on the crowded bands more enjoyable.

Neglecting to apply the operating procedures as outlined in this document will probably not send you to jail, but it will certainly result in inferior operating practice from your side.

Attachment 1: International Spelling and Phonetic Alphabet

Letter	Phonetic word	Pronunciation	Letter	Phonetic word	Pronunciation
A	Alpha	**al** fah	N	November	no **vemm** ber
B	Bravo	**bra** vo	O	Oscar	**oss** kar
C	Charlie	**tchar** li	P	Papa	pah **pah**
D	Delta	**del** tha	Q	Quebec	kwe **bek**
E	Echo	**ek** o	R	Romeo	**ro** me o
F	Foxtrot	**fox** trott	S	Sierra	si **er** rah
G	Golf	golf	T	Tango	**tang** go
H	Hotel	ho **tell**	U	Uniform	**you** ni form
I	India	**in** di ah	V	Victor	**vik** tor
J	Juliette	**djou** li **ett**	W	Whiskey	**ouiss** ki
K	Kilo	**ki** lo	X	X-ray	**ekss** re
L	Lima	**li** mah	Y	Yankee	**yang** ki
M	Mike	**ma** ik	Z	Zulu	**zou** lou

Attachment 2: The Q Code

CODE	QUESTION	ANSWER OR MESSAGE
QRG	What is the exact frequency?	The exact frequency is ...
QRK	What is the readability of my signals?	The readability of your signals is: 1: bad, 2: Fairly bad, 3: Reasonably good, 4: Good, 5: Excellent.
QRL	Are you busy? Is the frequency in use?	I am busy. The frequency is in use.
QRM	Are you interfered with?	I am interfered with. 1: I am not at all interfered with, 2: Slightly, 3: Moderately, 4: Strongly, 5: Very strongly.
QRN	Are you bothered by atmospherics?	I am bothered by atmospherics. 1, Not at all, 2. Slightly, 3. Moderately, 4. Strongly, 5. Very strongly.
QRO	Should I increase power?	Increase your power.
QRP	Should I decrease my power?	Decrease your power.
QRS	Should I decrease my sending speed?	Decrease your sending speed.
QRT	Should I stop my transmission?	Stop your transmission.
QRU	Do you have anything for me?	I have nothing for you.
QRV	Are you ready?	I am ready.
QRX	When will you call me back?	I will call you back at ... Also: wait, standby
QRZ	Who was calling me?	You are called by ...
QSA	What is the strength of my signals?	The strength of your signals is: 1. Bad, 2. fairly bad, 3. Reasonably good, 4. Good, 5. Excellent.
QSB	Is my signal fading?	Your signal is fading.
QSL	Can you confirm reception?	I confirm reception.
QSO	Can you make contact with ... (me)?	I can make contact with ... (you).
QSX	Can you listen on ...?	Listen on ...
QSY	Shall I start transmitting on another frequency?	Start transmitting on ... Also: change frequency (to ...)
QTC	Do you have a message for me?	I have a message for you.
QTH	What is your location (latitude and longitude or by name of the location)?	My location is ... latitude and ... longitude or : my location is ...
QTR	What is the exact time?	The exact time is ...

THE AUTHORS:

John **ON4UN** was introduced to the wonderful world of amateur radio by his uncle Gaston ON4GV. John was merely 10 years old. Ten years later he obtained the call ON4UN. John's interest in technology and science led him to become an engineer and his entire professional career was spent in the telecom world. All along he remained active on the bands, which has resulted in nearly half a million contacts in his logs. In 1962, 1 year after he received his callsign, he took part in his first contest, the UBA CW contest, which he won. This was the beginning of a near 50 year long amateur radio career in which contesting and DXing especially on the lower HF bands have played a major role. On 80 meters John has the highest number of DXCC countries confirmed worldwide (he is holder of the DXCC 80m award #1 with over 355 countries confirmed) and on 160m he has the highest country total outside the US with over 300 countries confirmed. John also was the first station world wide to obtain the prestigious 5B-WAZ award.

In 1996, ON4UN represented Belgium at WRTC (World Radio Team Championship) in San Francisco together with his friend Harry ON9CIB. WRTC is commonly called *the Olympic Games of Radio Contesting*.

A highlight in John's amateur radio career was undoubtedly his induction into the *CQ Contest Hall of Fame* in 1997 and into the *CQ DX Hall of Fame* in 2008, honours which until then had been bestowed upon only a handful of non-American hams. John wrote a number of technical books concerning our hobby, most of which are published by the ARRL (the American IARU Society). These covered mainly antennas, propagation and operational aspects concerning the lower HF bands. He also wrote technical software on the subject of antennae, including mechanical design of antennas and towers. Together with Rik ON7YD, he is the co-author of the UBA handbook for the HAREC-license. Already in 1963, as a very young ham, he got involved in Amateur Radio society affairs and became HF Manager for the UBA for a short period. More recently John served as President of the UBA between 1998 and 2007.

John combined his experience and expertise with that of his friend Mark ON4WW, to write this unique handbook *Ethics and Operational Procedures for the Radio Amateur*. A trigger to write this book was the enormous success of ON4WW's article *Operating Practice*, which was incorporated in the UBA HAREC handbook. *Operating Practice* is available in more than 15 languages on Mark's website, and has been published worldwide in a large number of ham radio magazines.

Mark **ON4WW** too, was barely 10 years young when he was bitten by the radio bug. His initial call in 1988 was ON4AMT, which he traded for ON4WW a few years later. Right from the start Mark was particularly interested in contesting, which may be one of the reasons for his special interest in correct operating procedures on the bands. In 1991 he met ON4UN and after some visits to John's place he quickly became a CW buff and in addition a supporter of the more difficult HF bands, 80 and 160m. In the mid-nineties, Mark was one of the key operators at the OTxT contest station of the local UBA club TLS, a contest station which was located at ON4UN's place. In that period this station won world wide first place (multi-single) three times as well as first places for Europe in several other CQWW contests.

In 1995 Mark joined the United Nations and went on a mission to Rwanda. In the following years he was sent on UN missions to several other African countries and each time he was active on the bands and especially on 160m and 80m (9X4WW, S07WW, EL2WW etc.). Later he showed up from Pakistan (AP2ARS) and Afghanistan (YA5T) as well as from Iraq (YI/ON4WW). Other calls Mark used in that period were JY8WW, J28WW and 9K2/ON4WW. Mark's last mission for the UN was in Gambia (C5WW) in 2003.

In 2000 Mark realized one of his dreams, going on a major DXpedition. He was part of the record setting FO0AAA expedition to Clipperton Island in the Pacific, where the crew made 75,000 QSOs in just 6 days. In that same year he was also part of the A52A DXpedition to Bhutan. Still in that same year he represented Belgium, together with Peter ON6TT, at the WRTC in Slovenia where they scored first world wide in the SSB category. Two years later, in 2002, the same team represented our country again at WRTC in Finland.

Over the years Mark has gained a tremendous amount of operating experience. Specifically he has operated for long periods at both ends of the pileups. He has witnessed a lot of operating practice that was and still is today capable of vast improvement. Hence the publication of his article *Operating Practice*, and now his contribution to this more elaborate publication.

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SOLID 20 WATTS

S. Venkataraman, VU2SV

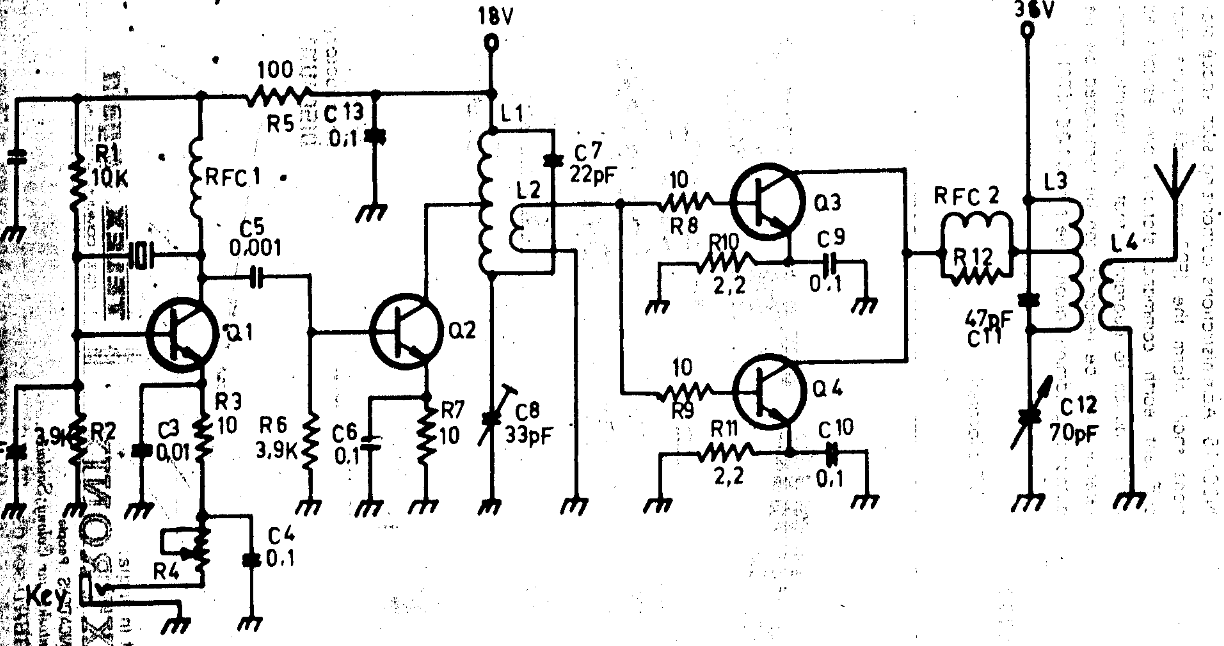
This fully solid state transmitter is capable of taking an input of 18 to 20 watts and makes use of silicon power transistors like SL 100 and 2N 3054. Though these transistors are meant for audio work, many experimenters had success with SL 100 using it as a Xtal oscillator transmitter with a DC input of upto 3 watts. The efficiency may not be comparable to that of an (RF) power transistor. Even a fifty per cent efficiency can easily give an output of about 10 watts. Here we are giving only the circuit diagram of the crystal controlled transmitter and a power supply for it. Experiments are going on for adding a stable VFO and a modulator and the results will be published very soon. The power supply will meet the power requirements of a VFO and a modulator and the transformer is designed as such. The circuit is simple and straightforward Once the components, coils and the P.C board are ready, the whole assembly and soldering will take only a couple of hours. An SL100 / CL100 silicon power transistor (Q1) is used as pierce crystal oscillator. The output from the collector of Ql is fed to the base of a second SL100/CL100(Q2) through the capacitor C 5 and the stage operates on class C mode. The collector of Q2 is connected to a low impedance tap on the coil Ll. Ll is tuned to resonance on 7 Mhz with the help of a philips 33pF air dieelectric trimmer. There is a parallel capacitor of 22 pf connected across Ll. The link coil L2 feeds the excitation to the bases of the output transistors Q3 and Q4 through equalizing series resistors of 10 ohms ½ w each. These emitter resistors R8 and R9. 2 2 ohms each give protective bias to the final transistors. Ql and Q2 are also protected likewise with emitter resistors R2 and R7. Two ferrite beads are slipped (one each) on the leads of R8 and R9 at the base ends of Q3 and Q4. These ferrite beads prevent or kill any VHF or UHF parastic appearing at the bases of Q3 and Q4. This is in addition to R8 and R9 serving as stopper resistors.

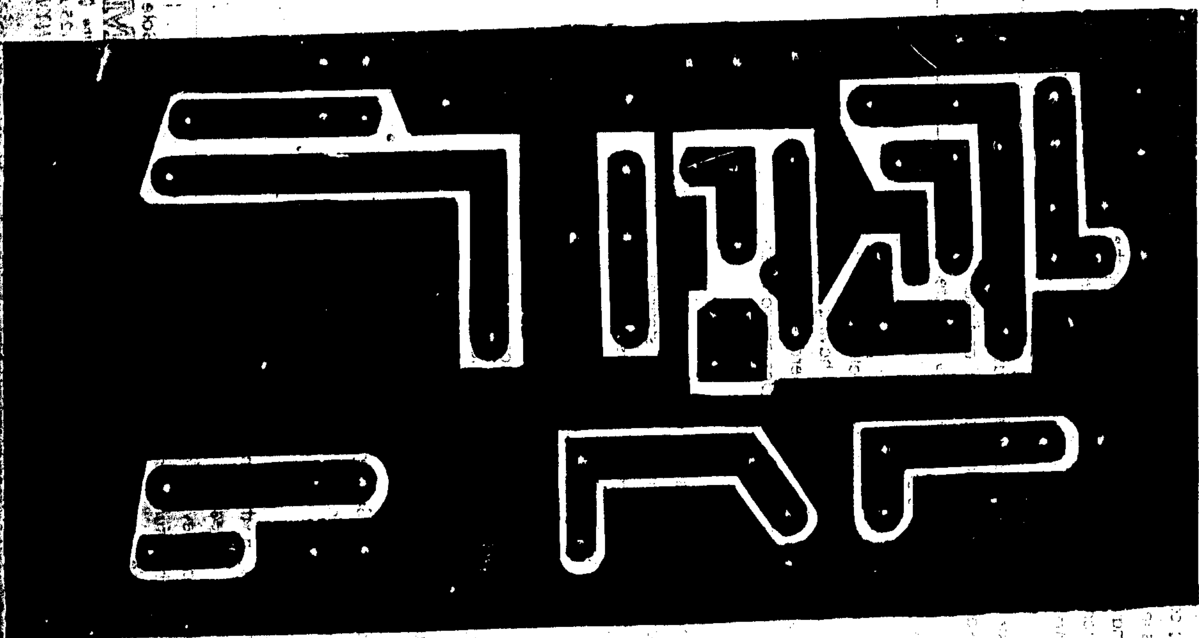
Transistor Q2 is mounted on a heat sink of not less than 4 sq. inches The heat sink is made out of 18 SWG alluminium sheet. The final transistors are mounted on a heat sink which in turn could be mounted on the rear of the proposed metal cabinet. The effective area of the heat sink should be more than 40 sq. inches. The heat sink is isolated from the metal casing of the transistors by mica separators. The P.A. works under class C condition. A full-size layout of the printed board is given elsewhere and it should serve as a guide to those who would like to duplicate the project. A screen made of 18 SWG Alluminium sheet about 2" across and running to the entire width of the printed board (lay-out) serves as a shield between the driver and PA stages. This prevents self oscillation between these stages and is a must The collectors of the output transistors are connected to a tap on the tank coil L2 through a parasitic suppressor RFC2. L2 is tuned to resonance with a Philips 70pf concentric air trimmer and a 47pF tubular ceramic capacitor across it. The RF output to the antenna is taken through a 4 turn link wound over the middle of L2 with hook up wire The connections to the key, Xtal, antenna etc. are all brought to the front panel. As the transmitter is meant only for the 7 Mhz band, very little adjustment of the driver and final tank coils is needed. However suitable variable capacitors could be used instead of the trimmers and they could be controlled from the front panel.

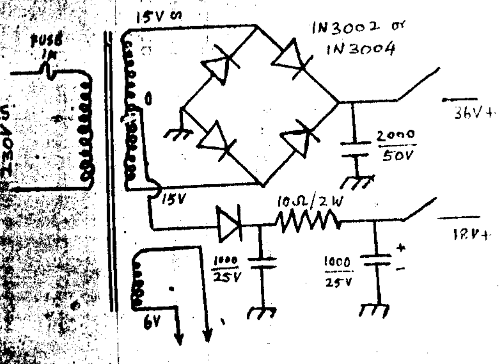
The transmitter requires a dual supply of 18 and 36 volts DC This could be easily provided by having a centre-tapped secondary of 15-o-15 volts RMS @ 1 ampere. A full-wave bridge rectifier is used across the entire winding and four IN4007 (EC4007) silicon rectifiers are used in the bridge. The power supply includes the D.C. requirements of VFO and modulator also.

Wiring and testing is straight forward. It is advisable to check each and every component for its value before it is soldered into circuit. First wind all the coils and attach the leads to the taps and solder them in position. Then wind the secondary links over them. After completing the wiring the p.c. board is checked for any short circuit or any mistake in the placement of components. After making sure the wiring is right in all respects, the 18 volts supply is connected to the P.C.B The two SL100s should be able to withstand the supply without breaking down. The crystal oscillator should go into oscillation instantaneously when the Xtal is plugged in and the key is pressed. The oscillation could be easily monitored on the station receiver. The preset R4 is adjusted to a point where the oscillation starts with the key up and reversed slightly to a point where the oscillation stops. The tuned circuit L1C5 is peaked by monitoring the strength of the output signal on the receiver. When C5 is adjusted the strength of the signal will have a definite peak. After peaking L1C5 the key is lifted.

A 7 Mhz antenna is connected to the transmitter output terminal. The 36 volts DC supply is switched on in the key up position and the two output transistors should be able to withstand the voltage on their collectors. Spurious and faulty devices will pack off, the moment the supply is switched on. This in turn will lead to a short circuit and the supply should be switched off immediately. In order to know that, it is safer to have a current meter in the supply lead having a







All capacitors in decimal values are disc ceramic. All capacitors in whole numbers are tubular ceramic, 10% tolerance. All resistors are 1/8W high stability carbon, 10% tolerance unless otherwise stated.

C8 and C12 are Philips concentric tubular trimmers.
RFC1 : 1 to 2.5mh RF choke
RFC2 : [illegible] turns enamelled wire 20SWG wound over R12 as former
R12 : 100 ohms ½W resistor
L1 : 25 turns close wound with 26 SWG enamelled copper wire over ½" former, tapped at 5 turns from the cold end.
L2 : Link 5 turns wound with thin hook-up wire over cold end of L1
L3 : 20 turns close wound with 20 SWG enamelled copper wire over 1" former tapped at 4 turns from cold end.
L4 : Link 4 turns wound with hook-up wire over the middle of L3
T1 : Power transformer - 230V a.c. primary; 15-0-15 1 amp. secondary 6.3V 1 amp for dial lamp and other 6V a.c. outlets

FSD of atleast 1 ampere. A fuse (1 ampere capacity) is also necessary. While testing the prototype we did lose a couple of transistors, the reason - bad manufacture. This happens, even if such devices are used in audio circuits. When we start tuning up the final, the signal picked up by the receiver will be strong enough to overload it. So earth the antenna terminal of the receiver at this time. The final tank circuit should be quickly tuned to resonance when the key is pressed. Keeping the final off resonance for a considerable time increases the collector dissipation to a great extent and it may result in permanent damage to them. Keep the key pressed for a few seconds only, each time the final tank coil is tuned. If an output meter or an SWR bridge is available it will be of great assistance in tuning the P. A.

If none is available a neon line tester will be helpful. L3 C12 is peaked for maximum output. Whenever the tank circuit is at resonance, the neon tester will burn bright. It may need a little touch up once the neon tester is removed At this time tuned circuit L1 C5 is touched up for maximum drive as indicated by an increase in the output. The link L4 is moved over the centre of L3 to get maximum output. In the prototype the link had to be placed almost at the centre of L3, While adjusting the tuning condenser C 12 care should be taken to avoid direct contact with the hot end of L3. There is enough Rf voltage there to give a burn.

The voltages are about the maximum for this operation and for the transistors used. Exceeding these values may lead to thermal runaway. For that matter, the final transistors should never be tried even for a few seconds without a proper load or a heatsink. The heatsink for the prototype is home-made but commercial heat sinks are readily available which may even do a better job. The total area of dissipation should be not less than 40 sq. inches. The heat sink may be fixed to the rear of the metal cabinet. The side panels help in further dissipation of heat. The metal cabinet may be made large enough to include the VFO and modulator.

Different methods of keying were tried viz. keying final only, keying the final and the driver stages, keying the driver stage only. In all these cases there was severe backwave. Therefore it was decided to key the oscillator itself. Then again, keying the supply voltage to Q, led to key clicks and sluggish oscillation. The present method of keying the emitter of Ql with a preset adjustment solved all these problems. The correct setting of the preset R4 is very important.

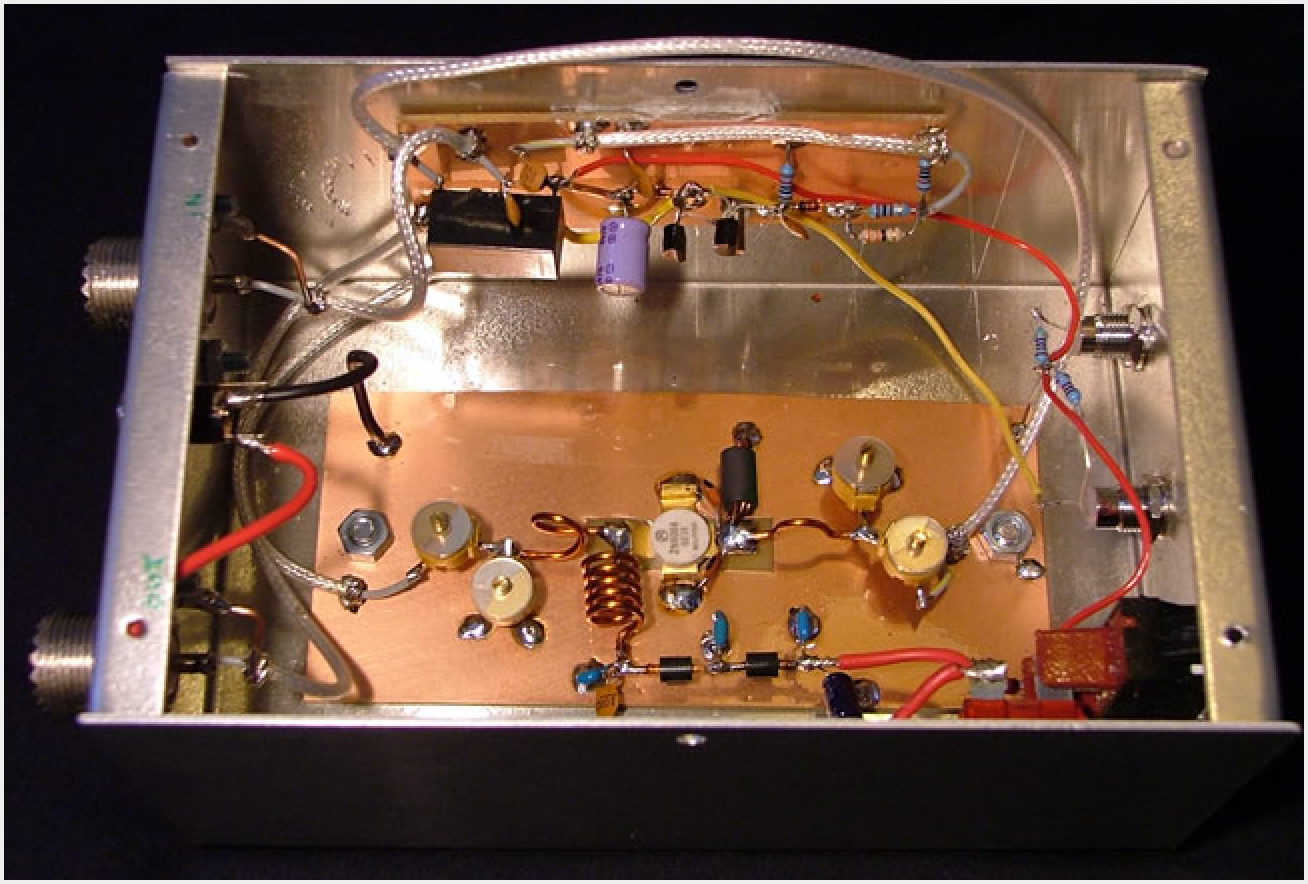
All the coils are close wound. Any former with the requisite diameter could be used. Even if the diameter is different the number of turns could be altered suitably, maintaining, at the same time, the ratio for the collector taps and links.

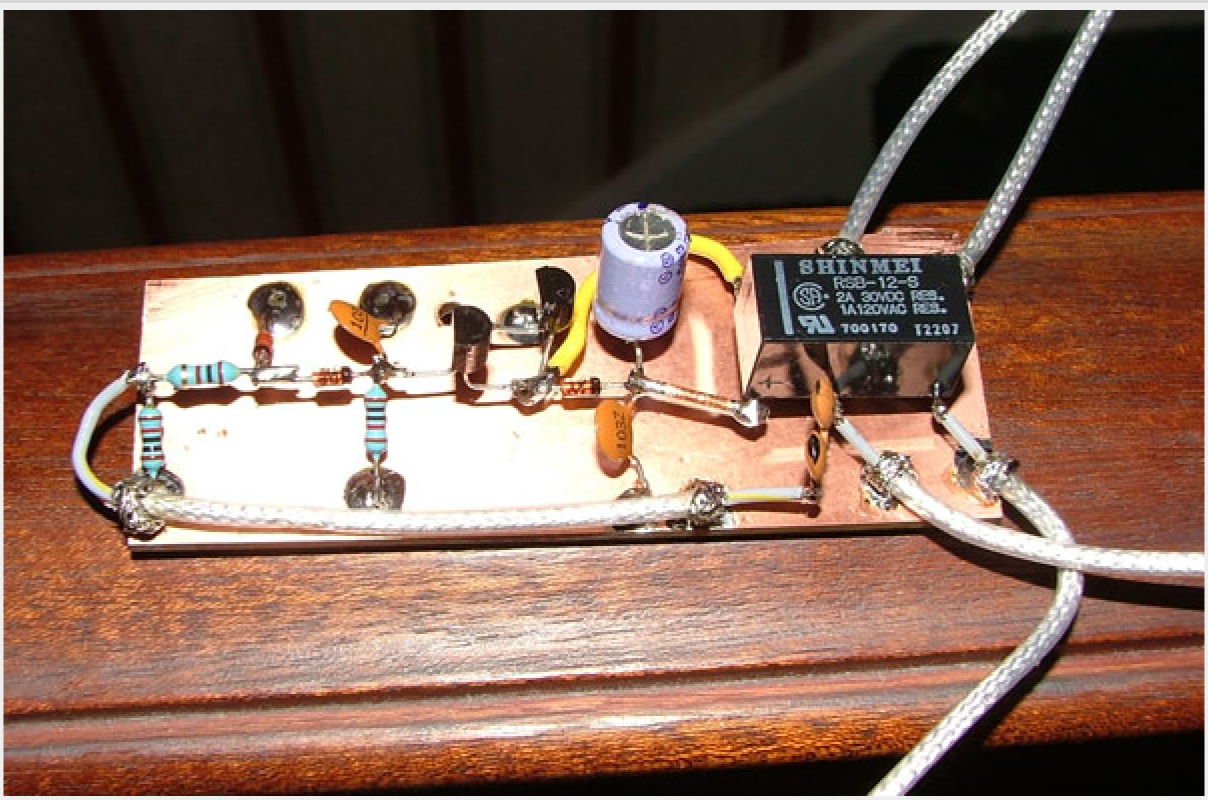
A word of caution before we close up. Don't tinker with a naked screwdriver. Any accidental short between two terminals may ruin the transistors. If there is any need for such probing viz. searching for a lc contact etc. use a P.V.C or wooden stick. While testing the transmitter for the first time feel the power transistor heat sinks with your thumb for any over heating. If so, the power should be switched off immediately and the reason for such over heating should be found out and rectified. It is better to wire stage by stage and check every stage for correct operation.

There are many possibilities of modification with this set up-such as using RF power transistors in the P. A - making it as a multiband VFO controlled transmitter - by giving 12V to the P.A. and slightly altering the link L4, it can be made as a portable mobile transmitter etc. etc.

PC boards may be available with Madras Amateur Radio Society very shortly at a nomial price.

2N6084 144MHz FM Power Amplifier




SHINMEI
RSB-12-S
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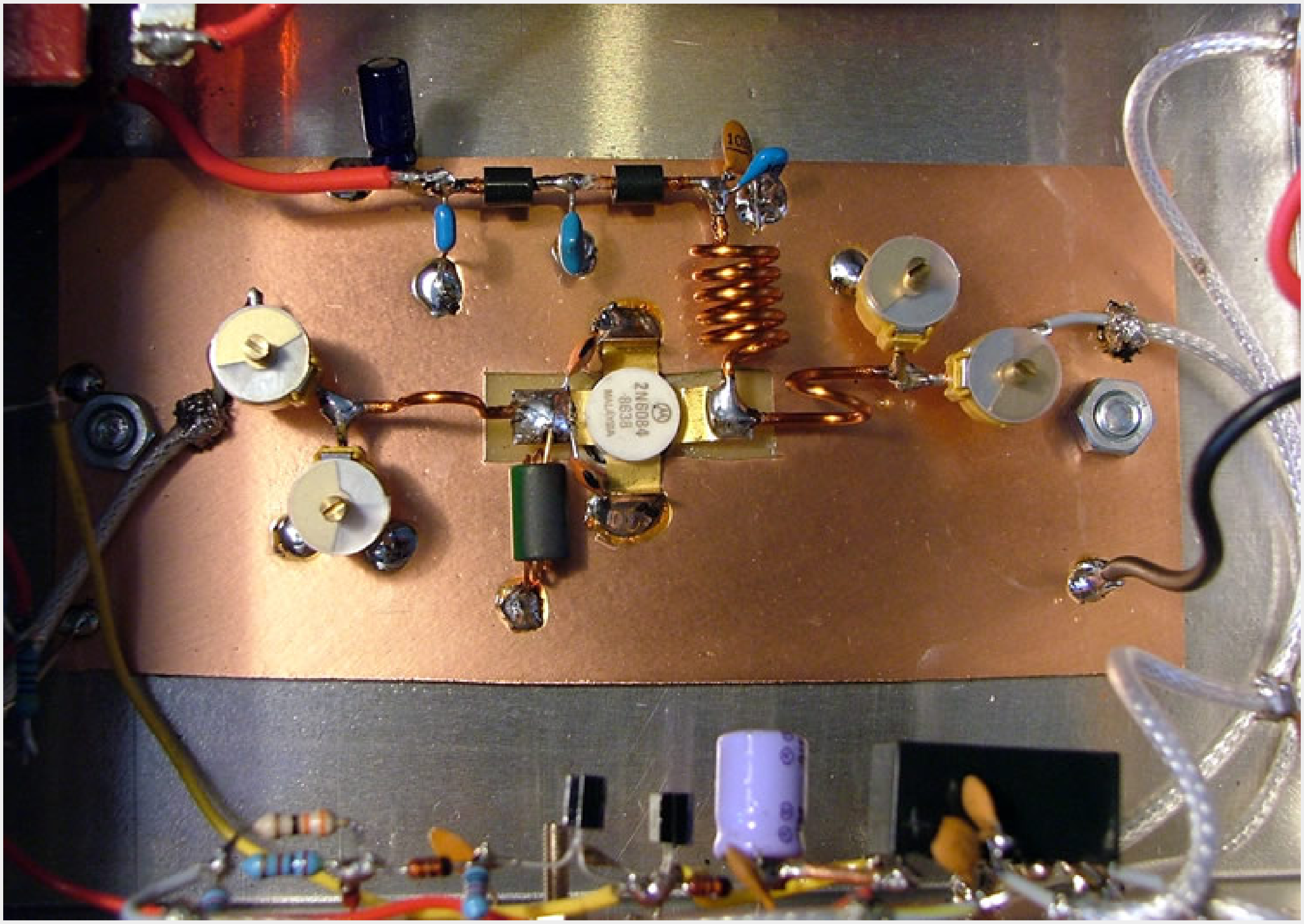
1A120VAC RES.
700170 T2207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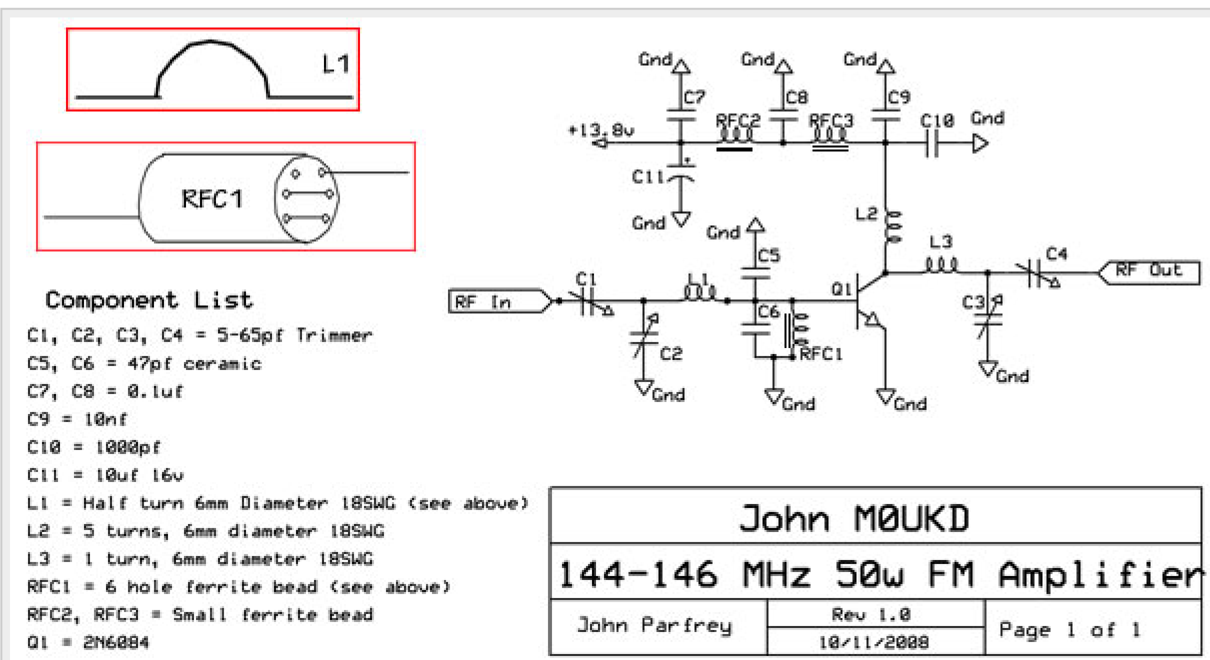
8638
MALAYSIA


OUT
IN


L1
RFC1
Component List
C1, C2, C3, C4 = 5-65pf Trimmer
C5, C6 = 47pf ceramic
C7, C8 = 0.1uf
C9 = 10nf
C10 = 1000pf
C11 = 10uf 16v
L1 = Half turn 6mm Diameter 18SWG (see above)
L2 = 5 turns, 6mm diameter 18SWG
L3 = 1 turn, 6mm diameter 18SWG
RFC1 = 6 hole ferrite bead (see above)
RFC2, RFC3 = Small ferrite bead
Q1 = 2N6084
+13.8v
Gnd
C7
C8
C9
C10
C11
RFC2
RFC3
L2
L3
C4
RF Out
RF In
C1
L1
C5
C6
Q1
C2
C3
RFC1
John M0UKD
144-146 MHz 50w FM Amplifier
John Parfrey
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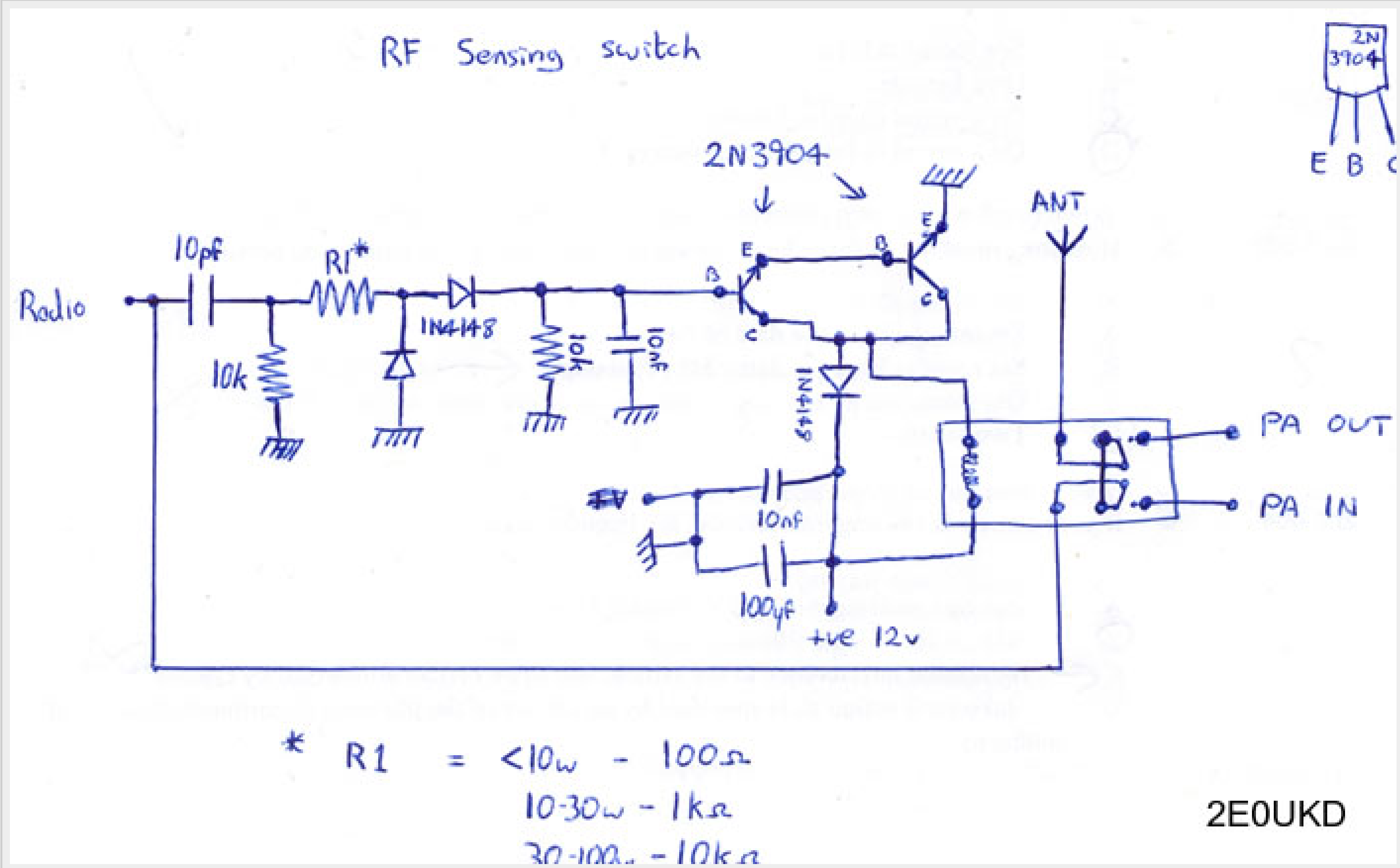

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DESIGN COCEPTS FOR RF-DC CONVERSION IN PARTICLE ACCELERATOR SYSTEMS

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H. Sapotta, *Karlsruhe University of Applied Sciences, Germany*

Abstract

In many particle accelerators considerable amounts of RF power reaching the megawatt level are converted into heat in dummy loads. After an overview of RF power in the range 200 MHz to 1 GHz dissipated at CERN we discuss several developments that have come up in the past using vacuum tube technology for RF-DC conversion. Amongst those the developments of the cyclotron wave converter CWC appears most suitable. With the availability of powerful Schottky diodes the solid state converter aspect has to be addressed as well. One of the biggest problems of Schottky diode based structures is the junction capacity. GaAs and GaN Schottky diodes show a significant reduction of this junction capacity as compared to silicon. Small rectenna type converter units which have been already developed for microwave powered helicopters can be used in waveguides or with coaxial power dividers.

MOTIVATION

The necessity to recover power in RF-driven particle accelerators can be shown with the example of the SPS. It utilizes a travelling wave (tw.) cavity, in which the charged particles travel with the phase velocity on the crest of an electromagnetic wave. To ensure the tw. operation, it has to be terminated by a matched load resistor (RL), resulting in an RF architecture shown in Fig. 1. A small part of the power from the RF amplifier is transfered to the beam or dissipated in the cavity walls, while the biggest part is converted to heat in RL. The SPS is composed of 4 tw. cavities, each operated at an average RF-Power of 379 kw. Thus altogether 1500 kw of RF-Power is converted to heat continuously and has to be dissipated in the underground tunnel.

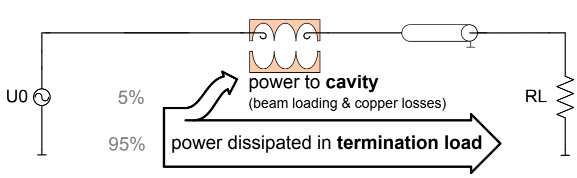

Fig. 1: Overview of a typical accelerator RF plant.

The most direct way to recover that RF-Power is to feed it back – with the right phase angle – to the input of the tw. cavity. Experiments showed that, due to different load situations caused by the beam, instability may occur. Hence a solution, which converts the power to an intermediate DC voltage, is pursued.

The general architecture can be seen in Fig. 2. The coaxial transmission line to RL is fitted with a large number of power couplers. Each output feeds one RF/DC converter module with a nominal design power of ≤ 1 kW. The DC output of the modules gets combined and will be fed back to the DC link of the tetrode RF amplifiers or supplied to the mains distribution grid.

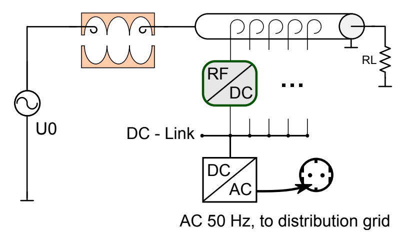

Fig. 2: Architecture of the RF - Recovery device.

RF DESIGN OF THE POWER DIVIDER

The coaxial line has a characteristic impedance of 50Ω and an air dielectricum. Its inner conductor diameter is 100 mm. The peak input power of 500 kW must be split in several hundreds of channels, each with a constant power level of 1 kW. Therefore a coupling of -27 dB is required at the input of the power divider. Allowing 10% of the input power to be absorbed in RL (90% power divider efficiency) results in a coupling of -17 dB for the last coupling antenna. The feasibility of coupling at this level has been studied. Different solutions have been analyzed:

A) Electrical coupling with a pin.
B) Electrical coupling using a pin with a capacitive plate at the end to increase the coupling.
C) Magnetic coupling using a loop.

A is too weak for our application. *B* and *C* give similar levels of coupling for the same dimensions. However it is much easier to materialize *B* than *C*, since no electrical contact is required inside the coaxial line. So the solution *B* has been chosen. The geometry of the coupling antenna and the electric field distribution around the pin and the capacitive plate are shown in Fig. 3. Varying the height of the pin and the length of the plate changes the coupling in the range from -27 dB to -17 dB. These parameters are chosen, so that the coupling is increasing from one stage to the next. While the power flowing along the divider is decreasing linearly from 500 kW to 50 kW, the power coupled out to the rectifier circuits maintains a 1 kW level. In this case 450 kW is coupled out to the rectifier circuits in 45 stages. Each stage has 10 coupling antennas distributed around the circumference of the outer conductor of the coaxial line. The overall length is about 5 m. Further investigations are

ongoing to reduce the length of the system.

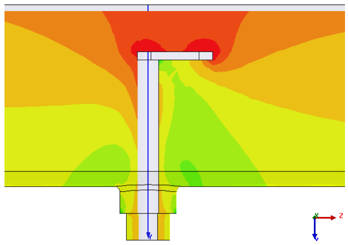

Fig. 3: Geometry of the coupling antenna and its electric field distribution.

RF TO DC CONVERTERS

The demands on the RF/DC modules are quite high, as the RF - Amplifier and the cavity are sensitive to reflected power. A proper 50Ω resistive match over a wide range of power levels has to be maintained. The radiation of harmonics on the device input must be inhibited. Aspects concerning the reliability, size and cooling have to be taken into account. Therefore different RF to DC converters are examined and their feasibility for this application is evaluated.

Cyclotron Wave Converter (CWC)

The CWC device is a new kind of RF to DC converter, patented by V.A. Vanke in 2003 [1].

The input RF-Power is used to accelerate electrons on a spiral path by a classic cyclotron structure. The rotational movement is then converted to an increase in longitudinal velocity by a specifically shaped external magnetic field. A "depressed collector" catches the electrons and converts their kinetic energy to a large DC voltage at the load resistance.

The feasibility as an energy recovery device for the SPS is summarized in Tab. 1. A positive aspect is the large input power per unit as well as the ability of the device to stand large peak powers. The wasted power of the SPS could be recovered with one single device, keeping the system complexity low and preventing losses through excessive deployment of RF power splitters. The main disadvantage of the device – for this application – is its need for a resonant cyclotron RF-Cavity. At the operating frequency of the SPS, which is 200 MHz, this would yield an exceptionally large device. The other disadvantages are the need for an ultra high vacuum, the maintenance requirements and the warm-up time.

Table 1: Positive and negative aspects of the CWC

Property	Value	Suitability
Power range [kW]	0.5 ... 50	✓
Achieved efficiency [%]	83	✓
Output voltage [kV]	1 ... 50	⚠
Operating frequency [GHz]	1 ... 50	⚠
Usable Bandwidth [%]	0.5 ... 5	✓

In [2] the CWC device has been implemented and tested for the recovery of RF Energy in a particle accelerator. In a simulation the authors were able to predict an overall RF to DC efficiency of 73% in the S-Band at an input power of 1 MW. This could not be confirmed in measurements because the electron collector broke down as the output voltage reached 125 kV. At these voltages, considerable engineering effort is needed to prevent losses through corona discharge, breakdown or even danger by the generation of X-Rays.

This shows that the CWC device is not easily scaled to higher power levels, as the high electron energy and the consequent high output voltage poses a limitation.

Rectenna circuits

The idea of using semiconductors to convert RF-Power to DC has been around since 1964 when W. C. Brown invented the rectenna. He was able – with this combination of antenna and diode-rectifier – to transmit a substantial amount of power wirelessly. The system operated at 2.5 GHz and used an array of 4480 small signal point contact diodes. The DC output power was 270 W, enough to build a demonstration helicopter which held itself in the air by RF-Power only [3]. At present times RF-Rectifiers are in the focus of research again. Three substantial reasons for this can be named:

- Wireless powered technologies as *Radio Frequency Identification* are getting more and more popular.
- Switch mode power converters are constantly miniaturized. The passive components can only be made smaller by choosing a higher operating frequency – which nowadays reaches the RF area.
- Significant advantages in semiconductor materials (band structure engineering) revealed a new generation of schottky power diodes which can be used up to the RF region.

Taking advantage of these points, it is possible to build an RF/DC converter, utilizing semiconductors, which can handle power levels in the 200 W range and does not suffer the drawbacks of ultra high vacuum devices. This provides the basis for the energy recovery concept, which is presented in the following sections.

CONCEPTUAL RF/DC MODULE

A general overview of the proposed RF/DC module is shown in Fig. 4. The RF signal from the power divider comes in through a 50Ω coaxial cable.

A "backup" termination resistor is connected to the input through a circulator. It ensures that the modules do not reflect RF power – under any circumstances – back to the cavity. This approach guarantees a failsafe system, which degrades gracefully in case of component failures. When a rectifier defect occurs (open or short), the overall recovery efficiency of the RF/DC array will be degraded but the operation of the particle accelerator will not be restricted in any way.

The matching network guarantees an optimum power transfer while not exceeding the maximum voltage or current ratings of the diode. The small bandwidth (¡2%) of the input signal allows the use of standard resonant matching techniques. Care must be taken with the design and simulation procedure, as the rectifier is a nonlinear device and its input impedance is likely to change with different input power levels [4].

The last block is the DC lowpass filter and the actual load. For simulation purposes it is modelled as a simple resistance. In the actual system, multiple module outputs will be combined to reach usable power levels [6].

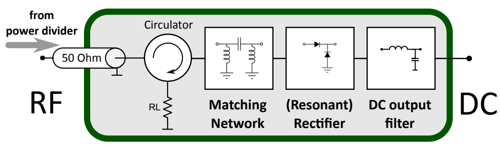

Fig. 4: Basic scheme of an RF/DC module.

DC-AC-Converter

To make use of the recovered power, it might be directly fed back to the DC - link of the tetrode RF-amplifiers or alternatively converted to standard utility AC power and supplied to the distribution grid. For this purpose, it seems to be most convenient to take power converters as they are used in solar power systems. These are rugged devices, which are available off the shelf. Only power converters equipped with an output transformer are feasible for this application as the circulator in the RF/DC modules forces a connection of one input node to earth. These solar power converters are using a maximum power point tracking system. That means, the input voltage of the converter is left constant, while the available current at that voltage defines the converted power. This kind of control system can easily be adopted in our application, as the rectifier has a well defined generator resistance.

Resonant Diode Rectifiers

The rectifier block converts 200W of RF-Power to DC in the most efficient way. Modern diodes like the *GS150TC25110* from IXYS can handle these voltage and current levels easily. The critical point for RF operation is its large chip area and thereby high junction capacity (for this diode $C_j = 120pF$ at zero reverse voltage). This equates to a parallel reactance of 6.6Ω at 200 MHz and does not allow the design of a traditional half wave rectifier. Anyway, by adding additional passive elements to the circuit, the energy stored in C_j can be recovered. These kinds of resonant rectifiers radiate less harmonics on the input, exploit the parasitic elements of the diode as an integral part of the circuit and allow the diode to turn on or off with a controlled dU/dt [4] [5] [6]. The disadvantages of these architectures are the relatively high voltage and current stress on the diode and the need to tune the circuit to a single input power and frequency.

A voltage output series resonant rectifier with a single *GS150TC25110* diode was simulated in PSpice. A realistic model was obtained from its datasheet. Parasitics of all components were included. The simulation showed an RF to DC efficiency of up to 88.8% at an output power of 196 W while staying in the safe area of operation of the diode. The efficiency got worse with a change of power level, frequency or load resistance. In a practical implementation this number is expected to drop to 70%.

Alternatively, schottky drain transistors might be considered. They can be operated in a diode like fashion by appropriately connecting the gate electrode. These devices are used in high power RF amplifiers at up to 2 GHz and promise a good performance for this application [7].

OUTLOOK

The basic building blocks of the energy recovery system have been shown and their tasks outlined. The next step is to obtain these blocks and build a working laboratory prototype. Alternative architectures for the resonant rectifier need some investigation in the form of simulations and real life measurements. Also, state of the art semiconductors, which are not yet commercially available, are going to be examined for this application.

ACKNOWLEDGEMENTS

The authors would like to thank Edmond Ciapala and Roland Garoby for supporting this project. We are grateful for the practical hints and assistance from: Johannes Broere, Reinier Louwerse, Eric Montesinos, Hans-Joachim Würfl and Veli Ylidiz.

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"HIS TRX" for the hiker!
A two band 1 chip + 1 transistor
1 watt QRP CW transceiver

(2000)

KLIK HIER VOOR DE NEDERLANDSE VERSIE

Portable with the small HIS transceiver, what a difference compared with the equipment in the shack!

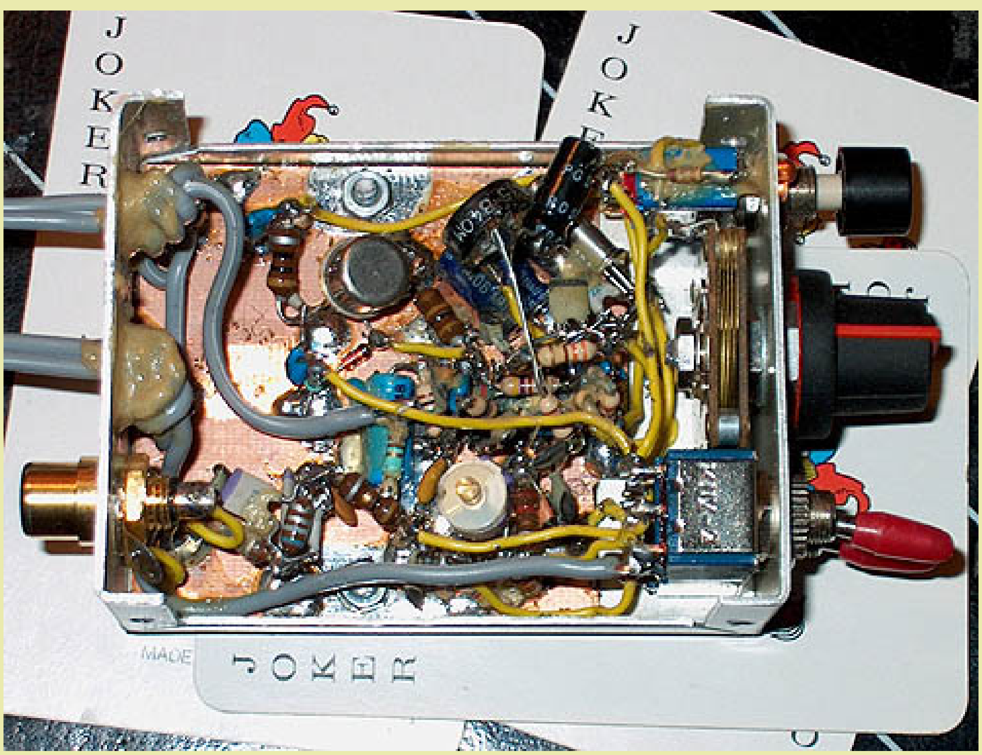
Very simple rig for in the backpack!
Back to Basics: portable on bare feet in the snow and in the woods with the HIS transceiver. That is where it is designed for! Enjoying the country air and the beautiful landscape, how nice and varied the radio hobby can be. All kinds of crazy activities are possible with this transceiver. You can have more fun with such a simple rig than with your home station in your shack!
This simple QRP power transceiver is designed for in the backpack of the barefoot hiker. Barefoot, because that is Back to Basics, real simplicity and that is his life style. The HIS transceiver is also Back to Basics, real simplicity. HIS is namely the abbreviation for He Is Simple! This small rig is extremely simplified, no volume control, simple VXO tuning and the CW key is a pushbutton. The tuning range is only 1 to 2 kHz. The performance of the direct conversion receiver is just sufficient. But it is possible to make a lot of nice QSO's with this simple rig, even with other QRP stations. It does not work always the first time, so do not give up too soon.

Small, simple, cheap and easy to control
Standing in the woods or in the snow is not as comfortable as being in the shack. So it has to be simple to control the transceiver. And it has to be possible to hold it in your hand. The HIS transceiver has a built-in CW key, only a few switches and only one tuning knob. You can use it even in the dark in you sleeping bag. It is small, simple and cheap. You do not have to be careful with it. If it falls into the mud or water or if it is damaged, no problem because

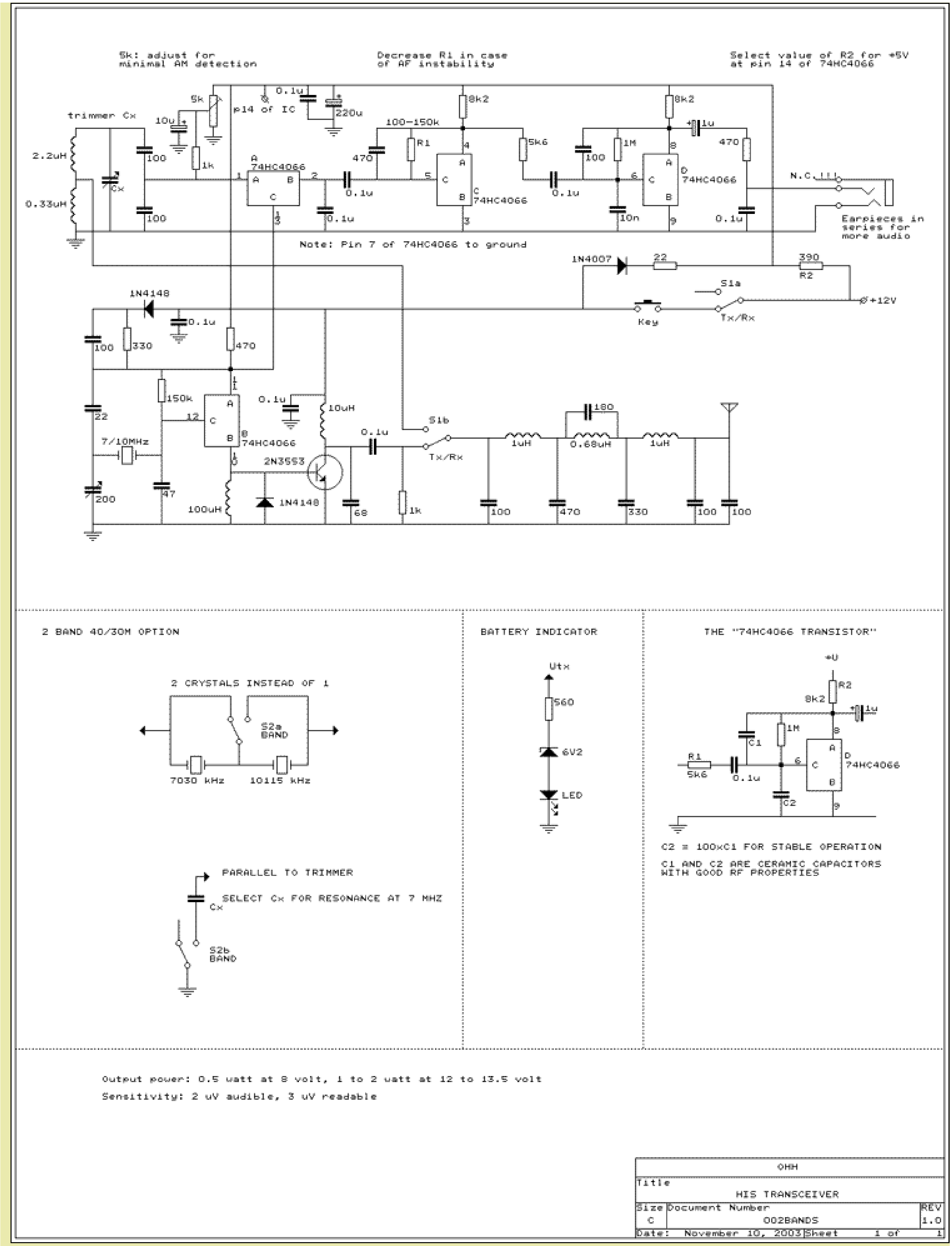
it can be repaired very easily. And they certainly do not steal it!
The complete station is so small that it fits in a lunchbox, including antenna's batteries and logbook!

QRP station in a lunchbox!

The design
This is a real minimum radio amateur technology QRP design, simple and non-professional.
One evening I tried if it is possible to use a C-MOS switch (1/4 of a 74HC4066) as an amplifier, just like a transistor. After a few hour's fight with oscillating circuits, I suddenly found out how to do that. Two capacitors with good RF performance are required for stable operation of the "74HC4066 C-MOS switch transistor". See for details the schematic diagram given below. Of course it is not a perfect amplifier, it is quite noisy, so the sensitivity of the receiver is only 3 uV. That is good enough for 7 MHz and 10 MHz, but not for the higher bands. I wanted to make it really simple, 1 transistor and 1 chip, but not too extreme. The LF output power should be sufficient to give perfect readable signals with a walkman headset. But there is no side tone oscillator and no volume control. The key is a simple pushbutton at the front of the transceiver (see picture).
It is easy to build the transceiver on a small single sided unetched PCB board as you can see on the photographs.



Real simple barefoot technology....



Circuit diagram

Circuit diagram
big diagram

Mixer
The mixer is one C-MOS switch of the 74HC4066 (Do not use a HCT!!!). It works perfect!!!

LF amplifier
Just two "74HC4066 C-MOS switch transistor".
It looks as if the input resistor of the first stage is missing. But you can find it at the input of the mixer.
If LF oscillation occurs, decrease R1. Select R2 so that in receive mode, the supply voltage of the 74HC4066 is approximately 5 volts.

VXO
The VXO is a "C-MOS switch transistor". In transmit mode, extra RF power is needed for the final transistor amplifier. This is obtained by the circuit consisting of the diode 4148 and 330 ohm/100 pF. In transmit mode, the VXO is also tuned a bit lower in frequency due to this circuit. So when you receive a station, the VXO signal should be higher than it's frequency. Here the values of the tuning ranges of my version:

Crystal Frequency (kHz)	Minimum Frequency (kHz)	Maximum Frequency (kHz)
7030.0	7029.5	7030.8
10120.0	10119.3	10121.2

Transmitter part
The VXO signal is amplified to 1 watt by a transistor 2N3553.
The 1k ohm resistor makes the amplifier more stable when mismatches occur. The 0.68 uH / 180 pF are tuned to the second harmonic of the 7 MHz transmit signal for extra suppression. One output filter is used for both 7 and 10 MHz.

Notes
Built via the ugly method (dead bug method). Parts are soldered at one side of the print.
Inductances are commercially available types looking like big resistors.
Do not use a HCT type but a HC type!
If LF oscillation occurs, decrease R1.
Select the value of R2 so that in receive mode, the supply voltage of the 74HC4066 is approximately 5 volts.
The two earpieces of the headphone are connected in series instead of in parallel for more audio signal.

Options
Battery indicator (led off if battery low). The 2 band version is also given here as an option.

Performance
The receiver is quite good for large signal handling as needed for 40 m operation in the evening. Perfect QSO's have been made, also with a lot of QRP stations, even long chats using inverted V dipole antenna's with the centre at 4 meters height.

Sensitivity: 3 uV signals are readable
3rd intercept: 8 dBm
Spurious responses: Better than -90 dB
RX current: 10 mA
Transmit power: 0.5 W at 8 V; 1.5 W at 12 V
Harmonic suppression: below 30 MHz: 43 dB, above 30 MHz: 55 dB

Back to Basics: portable on bare feet with the HIS transceiver!!

BACK TO INDEX PA2OHH

Microstrip Patch Antenna Design Principles

Ben Horwath

Outline

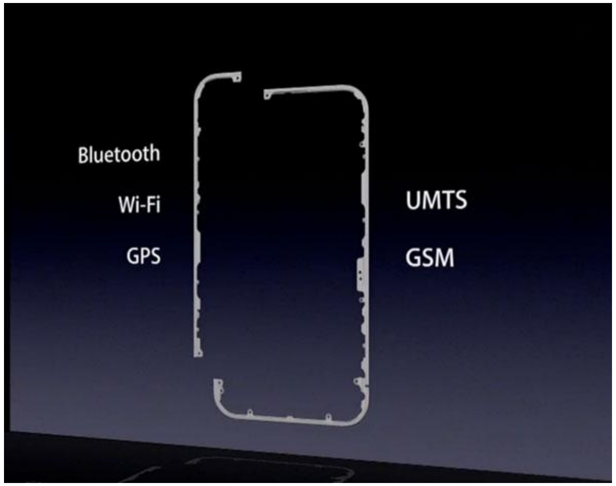
- Introduction
- Antenna basics
- Microstrip antennas
- Design methodology
- Design guidelines
- Footprint equations
- Circuit equivalent equations
- Quick example
- EM solvers
- PhD work-to-date
- Future efforts
- Some good references
- Questions

Introduction

- For consumer devices, wireless is everywhere!
  - LTE (700 MHz), GSM (850MHz/1.9GHz), Wi-Fi (2.4 GHz), Bluetooth (2.4 GHz), GPS (1.575 GHz)

With more coming: 5G (or whatever), Wireless Display, Wireless USB, etc.

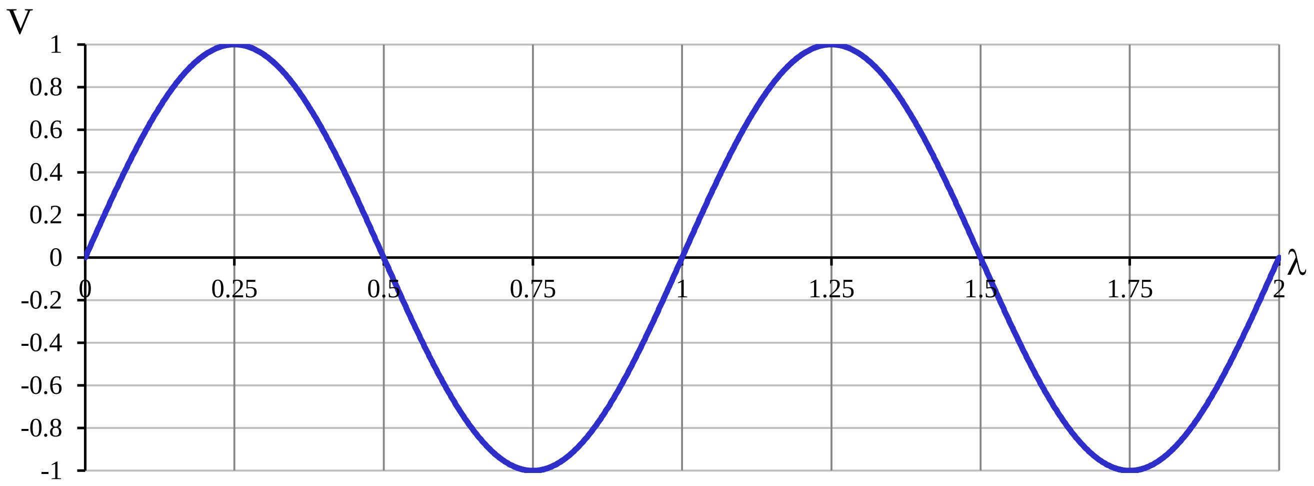
- Apple's iPhone 4 is popular science
  - But illustrates sizes and importance of good antenna design

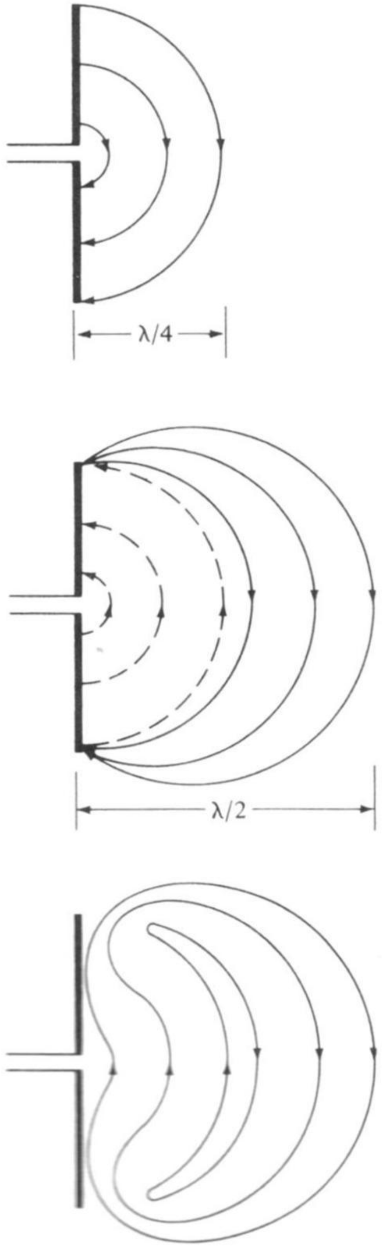


- Why microstrip antennas?
  - The patch antenna is a good place to start for antenna fundamentals

Antenna Basics

- How is radiation achieved?
- Wavelength is key: $\frac{\lambda}{2}$, $\;where\ \lambda = \frac{c_o}{f_r\sqrt{\epsilon_r}}$





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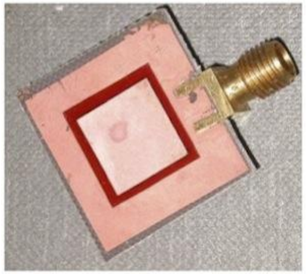
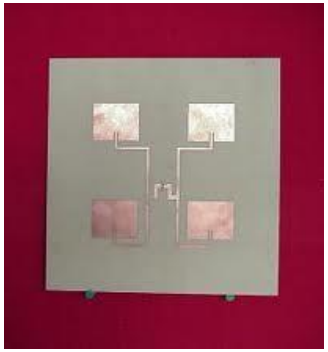


Microstrip Antennas



- With the microstrip antenna, $\lambda/2$ is a bit too big for consumer mobile devices
- Typically for space and military applications
- Easy to design/manufacture, yet very capable
  - Good value, great for antenna arrays
- Scale is better for millimeter wave RF (60+ GHz)

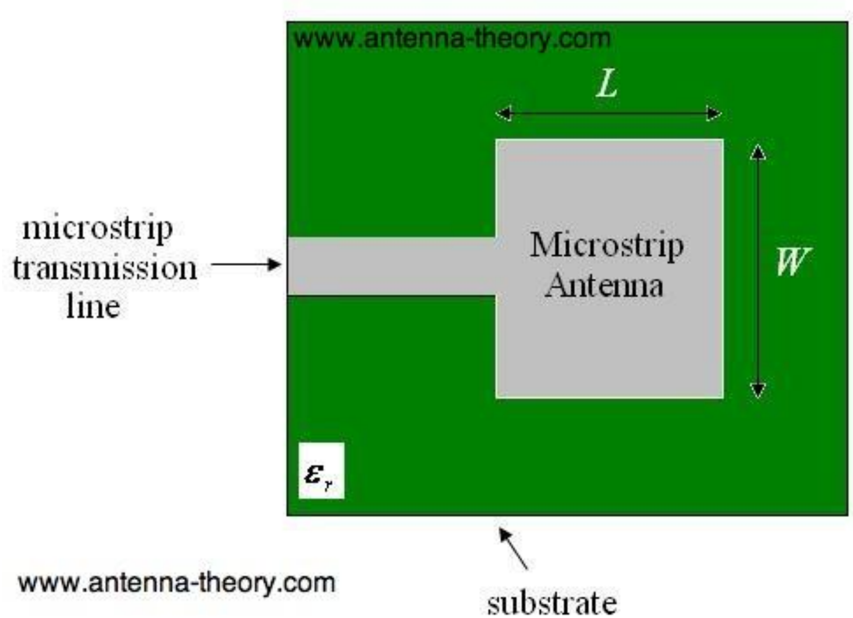
Santa Clara University

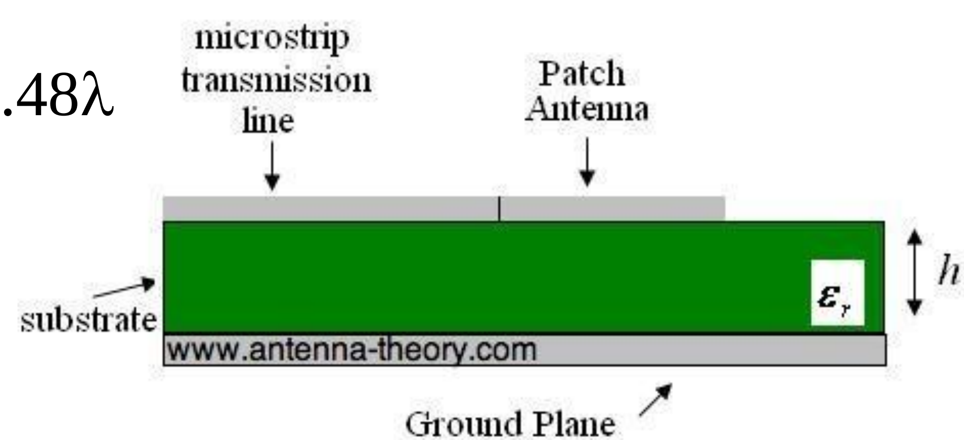
Design Methodology

- Find a “comfortable” model
  - Transmission Line – easiest, can be done in Excel
  - Cavity – higher accuracy, higher complexity
  - Full Wave – very accurate/adaptable, super complex
- Using specifications, generate initial design
  - Resonance frequency, gain, substrate, footprint, etc.
- Compare with an EM solver
  - Tune parameters such as ε_{reff} and ΔL (more details soon)
- Re-iterate design, prototype, measure
- Finalize design for manufacturing

Design Guidelines

- For microstrip antennas, a good 1st step is to assume a standard substrate
  - like Rogers RT/duroid 5880
- Importance of ε_r, h
- To avoid cross polarization, keep 1 < W/L <1.5
- Rule of $\lambda/2$ versus $\sim 0.48\lambda$





Footprint-Generating Equations

An initial guess at the patch width:

$$[1] \quad W = \frac{c_o}{2f_r}\sqrt{\frac{2}{\epsilon_r + 1}}, c_o \; is \; speed \; of \; light$$

Find effective parameters:

$$[2] \quad \epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}, W/_h > 1$$

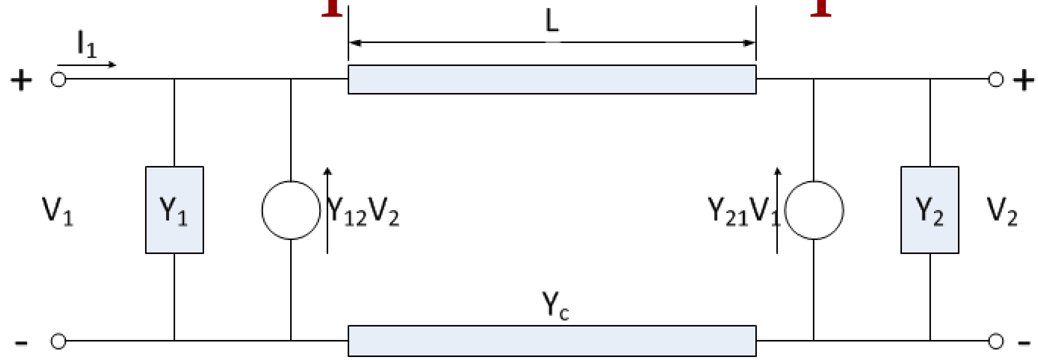
$$[3] \quad \frac{\Delta L}{h} = 0.412\frac{(\epsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\epsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

Get patch length:

$$[4] \quad L = \frac{c_o}{2f_r\sqrt{\epsilon_{reff}}} - 2\Delta L$$

* Balanis, Constantine A. *Antenna Theory: Analysis and Design*. Hoboken, NJ: John Wiley, 2005.

Circuit Equivalent Equations



[5] $Y_1 = G_1 + jB_1, Y_2 = G_2 + jB_2$

[6] $G_1 = \frac{W}{120\lambda_o}\left[1 - \frac{1}{24}(k_o h)^2\right], k_o = {}^{2\pi}/_{\lambda_o}$

[7] $B_1 = \frac{W}{120\lambda_o}[1 - 0.636\ln(k_o h)]$

[8] $G_2 = G_1, B_2 = B_1$

Via admittance transfer function:

[9] $\widetilde{Y_2} = \widetilde{G_2} + j\widetilde{B_2} = G_1 - jB_1$

[10] $Y_{in} = Y_1 + \widetilde{Y_2} = 2G_1$

[11] $Z_{in} = \frac{1}{Y_{in}} = R_{in}$

For this discussion we will ignore mutual effects

Quick Example

- Rogers RT/duroid 5880 chosen:
  - h=0.508mm, 100mm x 100mm board, ε_r=2.2
- Want an antenna for GSM, f_r=1.9GHz
- Use equations in Microsoft Excel
  - W=6.24cm, L=5.30cm, Z_{in}=151.8Ω
  - Feed set to be 50Ω (standard): W_o=1.6mm
- Confirm antenna using an EM solver
  - Sonnet yields Z_{in}=209.7Ω at 1.88GHz

Equations Implemented in Excel

er	2.2		
h	0.000508	m	
co	299792458	m/s	
fr	1.900E+09	Hz	
lo	1.578E-01	m	
ko	39.821055	rad/m	
W	0.0624	m	
ereff	2.1727		
DL	0.0003	m	
L	0.0530	m	
Le	0.0535	m	
G	0.0033		
B	0.0115		
Yin	0.0066		
Zin	151.8	Ohms	
Wo	0.00158	m	
ereff2	1.8721		
Zc	50.00	Ohms	
Gamma	0.504438	-2.97192	dB
VSWR	3.0358218		

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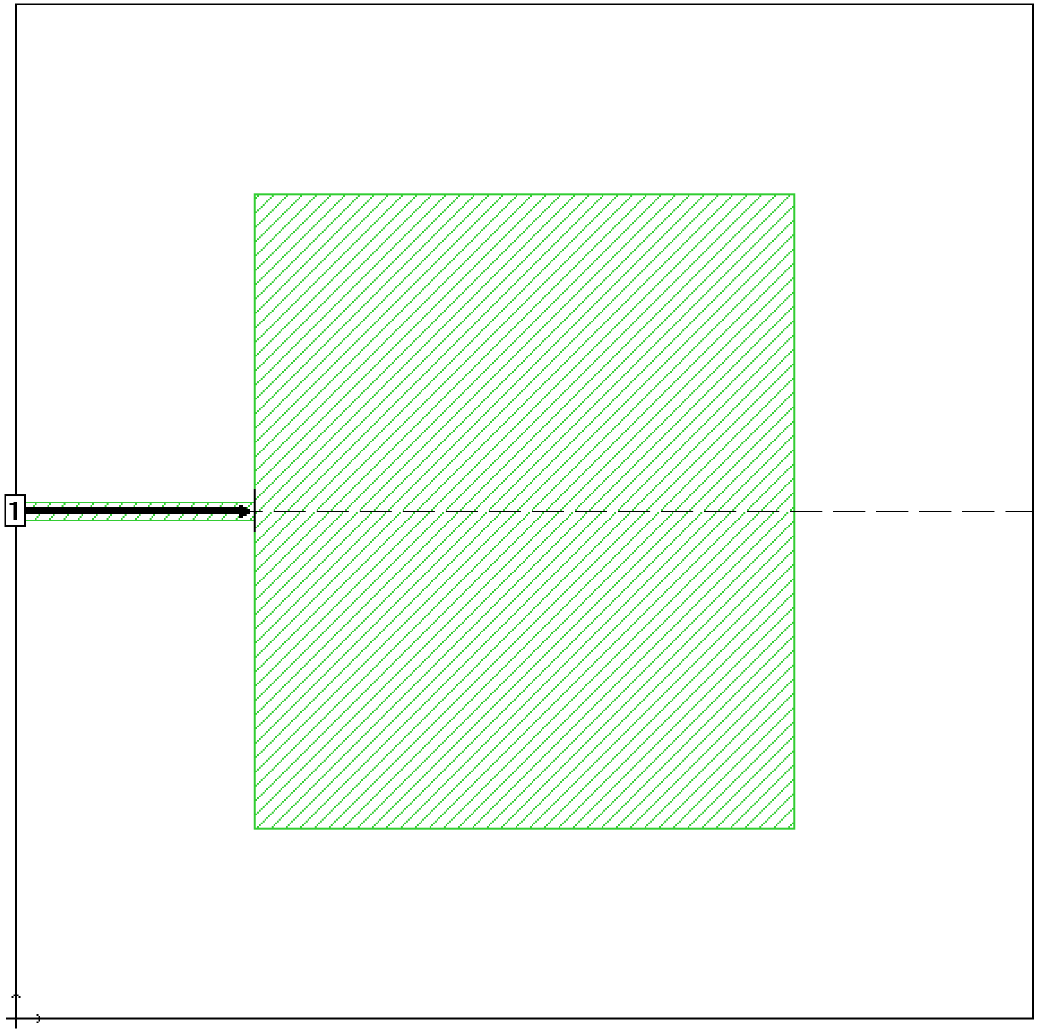
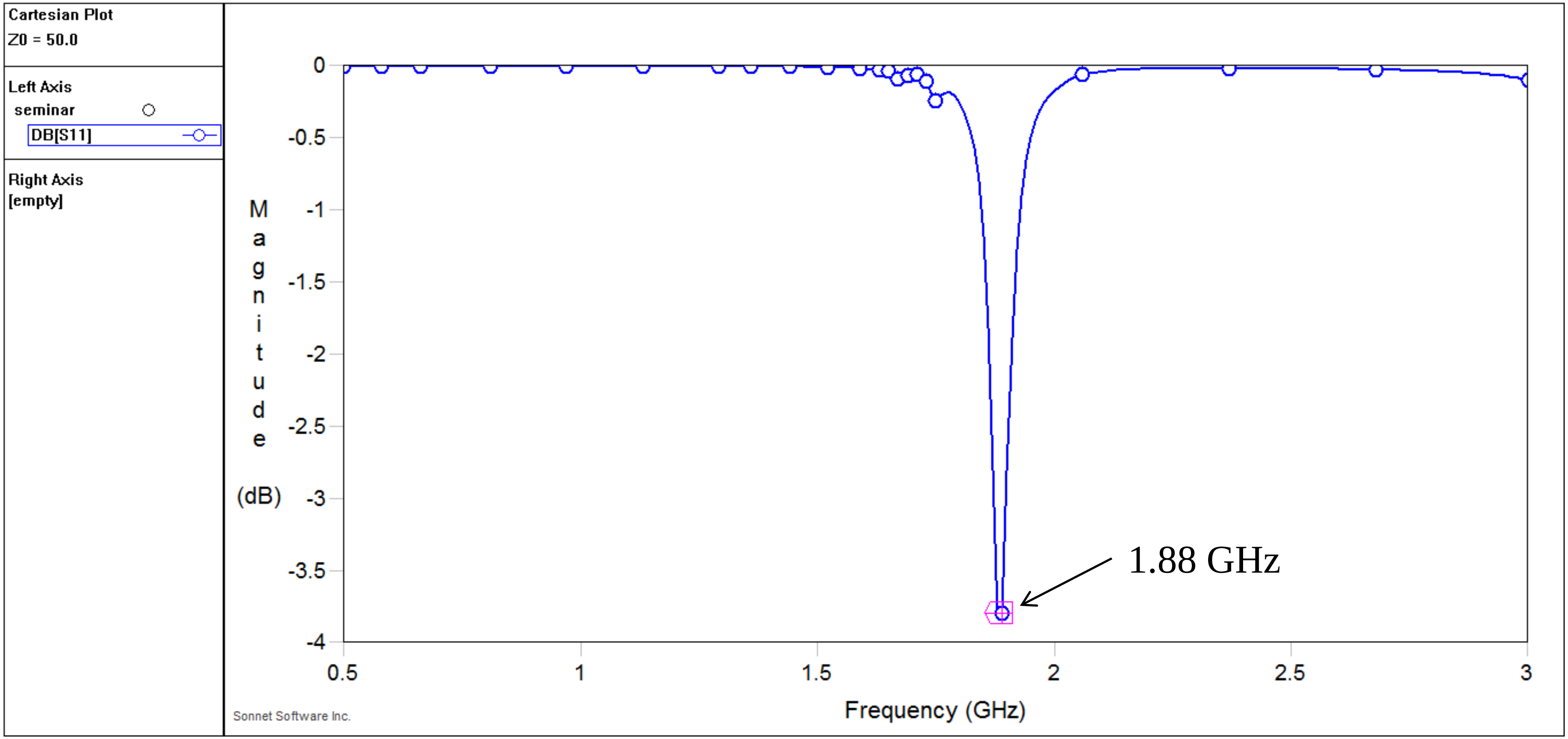
Sonnet Implementation



Sonnet S11 Response



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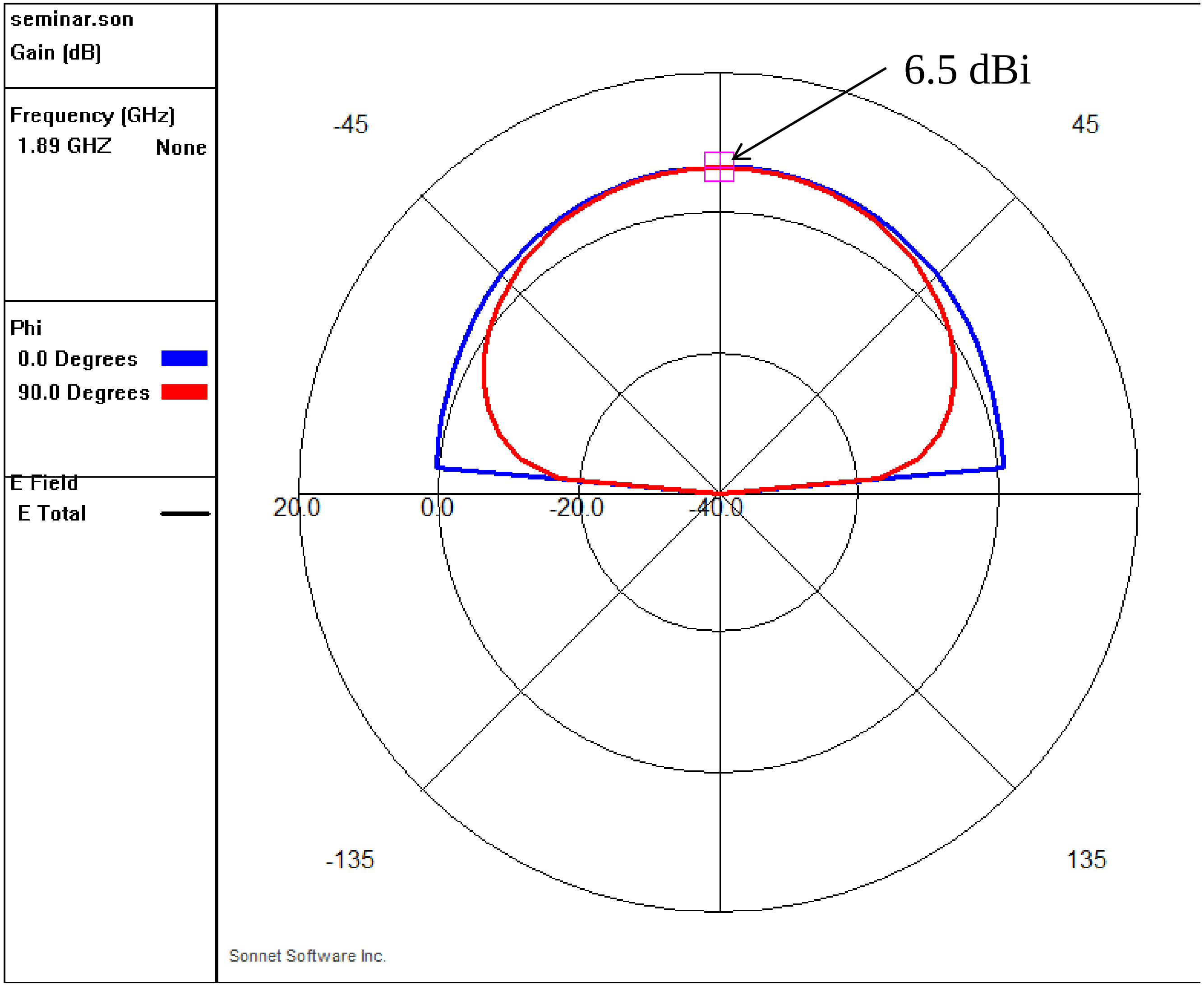
Sonnet Radiation Patterns



A Few EM Solvers

SONNET *

AWR Microwave Office (AXIEM)*

ANSYS HFSS*

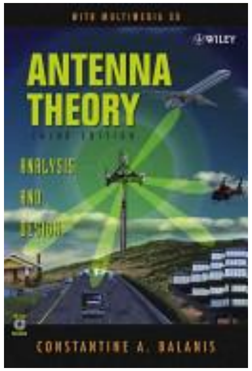
Agilent Technologies ADS*

FEKO Comprehensive Electromagnetic Solutions

* SCU Design Center

Some Good References

- Antenna Theory – Constantine Balanis
  - Used for Antennas I (ELEN 715)



- Microstrip Antenna Design Handbook – Garg et al
  - Title says it all, but a few inaccuracies have been found

- Antenna Theory and Microstrip Antennas – D.G. Fang

- www.antenna-theory.com

PhD Work-to-date

- Focus on tunable antennas
  - Add impedance elements to electrically change the characteristics of the antenna (Z_{in}, E field)
- 60 GHz on-chip tunable antennas and array
  - Adaptive field patterns tuned by IMPATT diodes
- Mantenna
  - Wearable antenna array operating at 50-500 MHz
  - Direction finding for military applications
- 77 GHz system optimization
  - Extending Prof. Al-Attar's monolithic transmitter work

Future Efforts

- Gain full theoretical control of the antenna
  - Change bandwidth, f_r, E field/directivity at will
  - Use a range of IMPATT locations and values
- Investigate adaptive array pattern control
  - Optimize via array geometry
- OTA for PhD completion
  - Develop a test system, work with industry
    - RF tx/rx chains plus control

Questions?

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Santa Clara University

EXCELLENT 30 METER RECEIVER FOR LOW POWER QRSS BEACONS AND PSK31

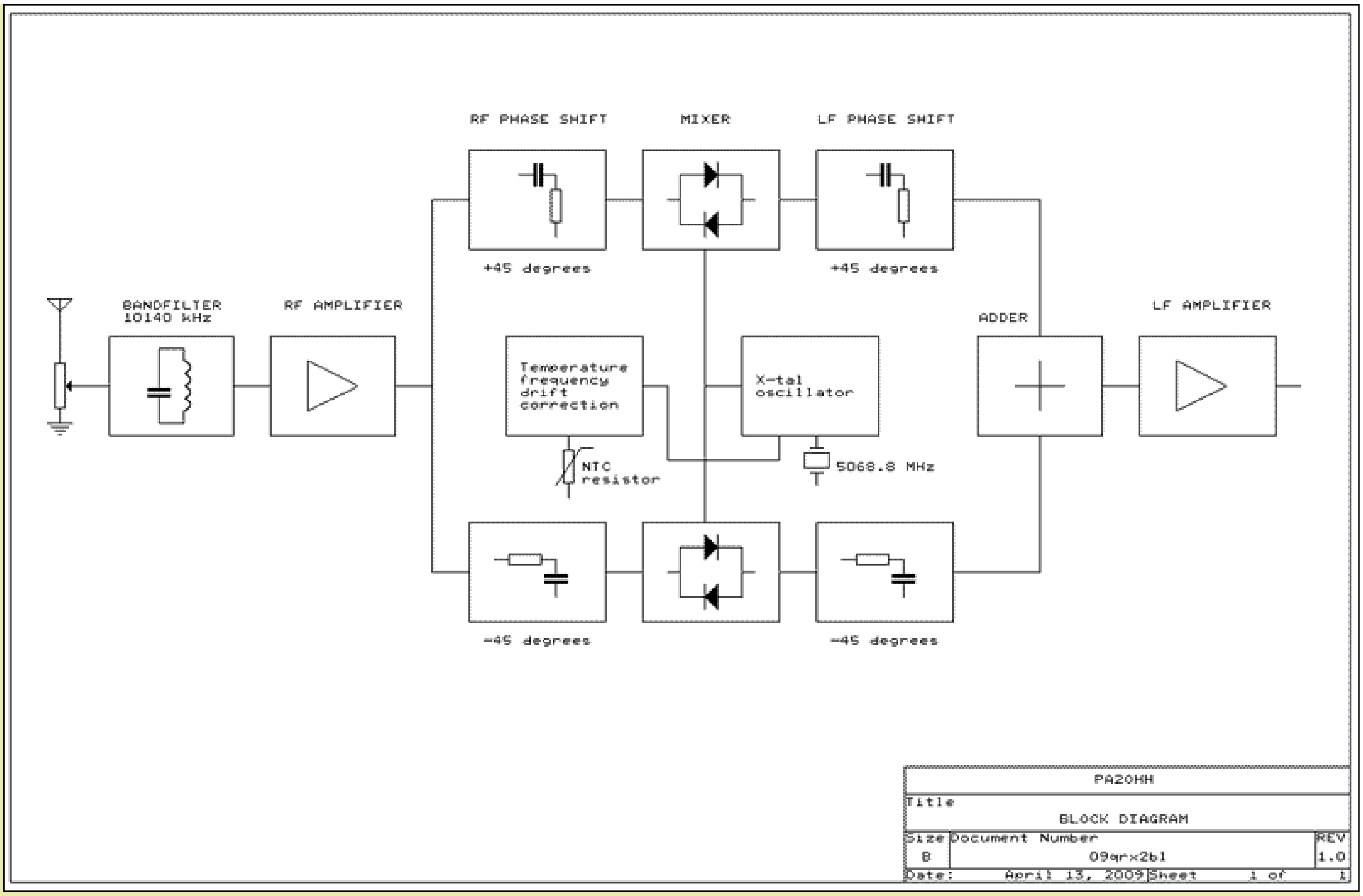
(2011)

KLIK HIER VOOR DE NEDERLANDSE VERSIE

Reception of very low QRSS beacon transmitters
There is a group enthusiastic radio amateurs that is doing experiments with very low powers. That is possible by using a very slow CW speed. QRS mean reduce your CW speed. With that extra S of QRSS they want to indicate that it is really a very low CW speed. A point lasts 3 or 10 seconds. Most of the activities take place in a band of only 100 Hz: 10140.0 to 10140.1 kHz in the 30 meters amateur band. The signals are so weak, that you cannot hear them. But you can see them on the monitor of the PC. The audio output of the receiver is connected to the sound card of the PC. With a special software program, you can make bandwidths of 0.3 Hz or even less and display the signals on the monitor.

The receiver suppresses the unwanted side band by means of the phase method. And a crystal filter improves the selectivity and avoids overloading by strong broadcast transmitters.

Excellent receiver with side band suppression, crystal filter and modified antenna circuit
It was quite simple to modify the simple direct conversion receiver with the phase method to a single side band receiver. Two mixers were required instead of one and simple phase networks in the RF part and LF part. As the frequency band of 10140.0 MHz to 10140.1 MHz is only 100 Hz wide, we can use two very simple LF phase networks consisting of one capacitor and one resistor. That is an advantage, because there is not so much space in the plastic housing of the receiver. And the receiver has to be supplied with batteries, these networks do not require any current. A wide band 90 degrees phase networks with op-amps in the audio part was not possible.



Block diagram. The phase networks do suppress 1 side band.
The Poljakov mixers do need a local oscillator signal of half the reception frequency.

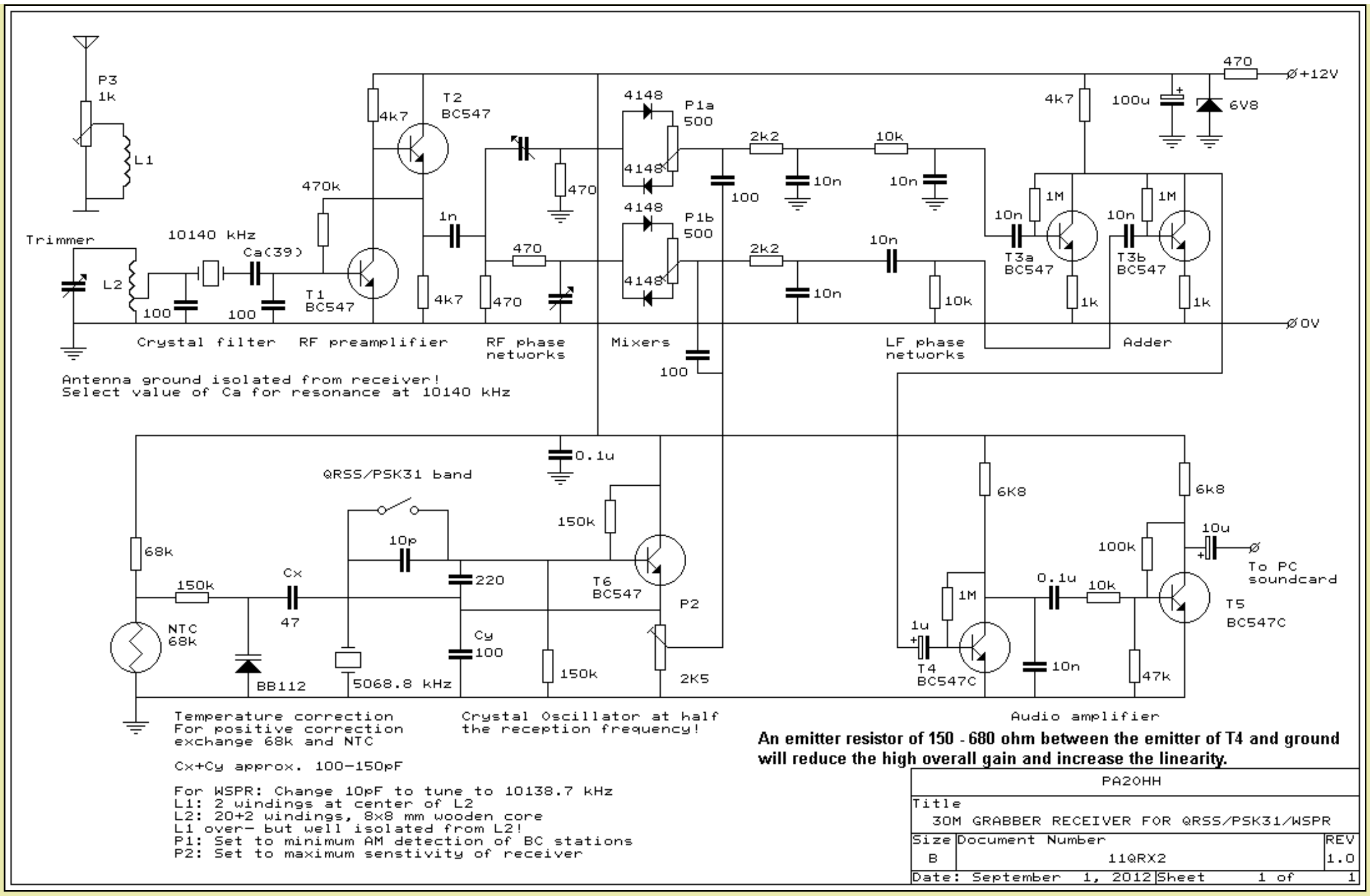
Explanation of the schematic diagram

We will start with the RF amplifier and RF phase networks. T1 is an ordinary LF transistor. The tuned circuit is adjusted by ear for maximum sensitivity. L2 is 20 windings on a wooden core of 8x8 mm with a tap at 2 windings to the base of T1. The antenna winding L1 of 2 windings is wound at the cold side of L2. This antenna winding is completely isolated from the receiver, so that conducted radio interference cannot come into the antenna circuit. L1 is wire with a thick isolation, so that the distance between L1 and L2 is large and the capacitance small. Wind L1 at the cold side of L2.

The (adjustable) potentiometer P3 of 1k is the RF control. It is used to avoid overloading of the receiver in the evening by strong broadcast stations. You can use an adjustable potentiometer as it is not adjusted so often, only once or twice per day. But with the crystal filter, there is no overloading anymore and you can set it always to maximum!

T1 is followed by an extra transistor T2 that transforms the high output impedance of T1 to a lower impedance. That is necessary to feed the phase network.

There are two 45 degrees phase networks between the RF stage and the mixers. They are adjusted by the trimmers. For that purpose, you do need a signal at the unwanted side band. Adjust the trimmers by ear to maximum suppression of this signal. You have to repeat it a few times, as the settings of each network do influence each other.



Circuit diagram
big diagram

Mixer and LF phase networks

The mixer is a so called RA3AAE or Poljakov mixer. It works with a local oscillator signal of half the reception frequency. And that is the frequency of a cheap, easily obtainable crystal of 5068.8 kHz. The oscillator level is quite important and can be adjusted by ear with P2.
With a good adjustment by ear of P1a and P1b, the sensitivity for strong AM signals can be reduced considerably.
After the mixer and the RF decoupling networks consisting of resistors of 2200 ohm and capacitors of 10 nF, you will find the LF phase networks. Each network is made of a capacitor of 10 nF and a resistor of 10 k ohm. The networks are designed for 1550 Hz, that is the center frequency of the 10140.0 - 10140.1 MHz band in my receiver. You have to modify them for other frequencies.

VXO

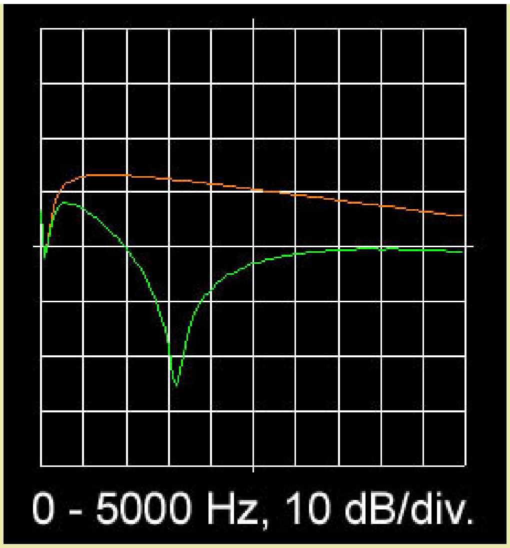
The crystal oscillator works approximately on 5068.8 kHz, just beside half the reception frequency. The exact value is not important, it is set during the calibration and corrected in the ARGO software program. By means of a switch and an extra serial capacitor, the frequency can be increased so that you also can receiver PSK31 stations working at higher frequencies..

Temperature stabilization

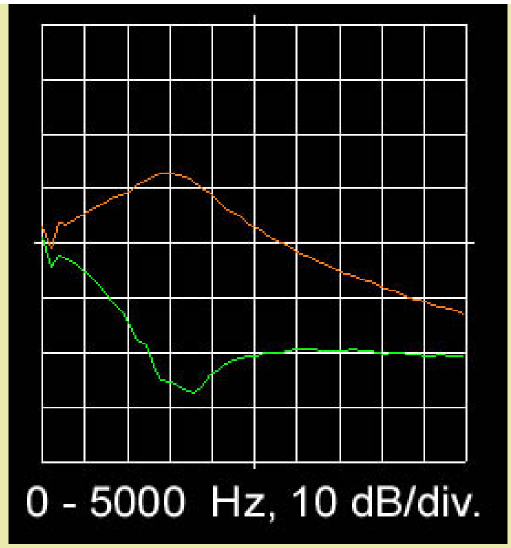
With a NTC resistor and a varicap, a temperature correction was designed and the drift reduced to less than 5 Hz between 10 C and 30 C. For an upwards frequency correction, the NTC has to be connected as in the diagram. For a downwards correction, exchange the NTC and 68k resistor. Of course you can also take a NTC resistor with another value. Exchange the 68k resistor then for a resistor with the same value as the NTC. Increasing Cx and reducing Cy increases the correction, reducing Cx and increasing Cy reduces the correction. Finding the correct value is a question of trying out while cooling down and warming up the receiver with various values of Cx and Cy.

The crystal filter

Between L2 and T1 is a simple crystal filter with 1 crystal of 10140 kHz, a series capacitor Ca and two capacitors of 100 pF to ground. The value of the capacitor Ca is chosen for resonance at 10140 kHz. For my crystal, 33 pF was too small (resonance frequency too high) and 47 pF too large (resonance peak too low). As I did not have a capacitor of 39 pF anymore, a capacitor of 18 pF and one of 22 pF were connected in parallel for a Ca value of 40 pF.



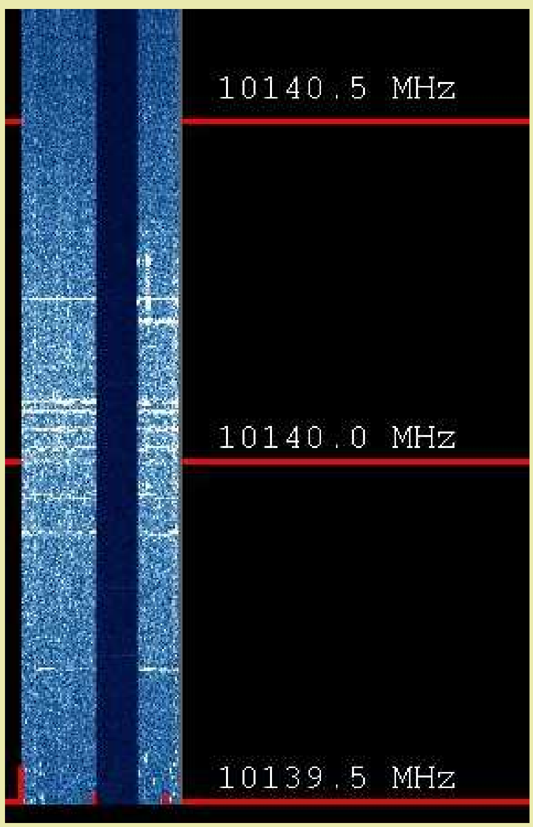
Side band suppression
only by the phase method



Side band suppression
with extra crystal filter

Frequency characteristic (orange line) and side band suppression (difference between orange and green line).
The reception frequency of 10140 kHz lies at the audio frequency of 1550 Hz in the graph.

The crystal filter is approximately 800 Hz wide. Wide enough to receive also WSPR signals between 10140.1 kHz and 10140.3 kHz. Strong signals outside the bandwidth of this very simple crystal filter are upto 30 dB attenuated! The AM detection of strong broadcast transmitters and also overloading of strong signals near the reception frequency are completely gone. The RF attenuator (the potentiometer P3 of 1k ohm at the input) does not have to be used anymore.



The spectrum. The noise peaks at 10140 kHz. When disconnecting the antenna, you can
see a dark strip in the spectrum. So the own noise of the receiver is really low.

Picture of the spectrum
The sensitivity of the receiver is excellent. You can see that on the picture here above of the spectrum. When the antenna is disconnected, you can see a dark strip in the spectrum, as the noise almost disappears. The noise of the receiver is almost negligible. In fact, the sensitivity is too good. Some RF attenuation is adviceable to increase the dynamic range. On the

picture, you can also see that the filter peaks on 10140 kHz. At this frequency, the noise is maximal. With use of such a spectrum picture, you can easily determine the correct value of Ca.

Alignment of the receiver

The tuned antenna circuit at the input is aligned by ear at maximum sensitivity.
The value of the capacitor Ca is chosen for resonance at 10140 kHz.
The temperature correction is adjusted by warming up and cooling down the receiver with various values of Cx and Cy.
The oscillator level is adjusted by ear at maximum sensitivity. Adjust it a little higher, so that the sensitivity decreases a little. At that point, the suppression of strong AM broadcast signals is better.
The potentiometers P1a and P1b are adjusted with a strong AM signal in the 10 MHz broadcastband for a maximum suppression of AM detection. If possible, use a (simple) AM modulated signal generator.
The two 45 degrees phase networks are adjusted by ear with the trimmers. For that purpose, you do need a signal at the unwanted side band. Adjust the trimmers by ear to maximum suppression of this signal. You have to repeat it a few times, as the settings of each network do influence each other. If you want, you can optimize the side band suppression by changing the values of the resistors in the LF phase networks a little. Then repeat the alignment of the trimmers of the RF phase networks.

Software

You can find much information and software about QRSS on the internet. I did use ARGO of Alberto, I2PHD. But why should you only make your own hardware? Making software is perhaps even nicer! So nowadays I do use my own software LOPORA. So now and then, you can see the pictures at grabber.htm.
When you tune the receiver exactly to 10138.7 kHz, you can also receive WSPR with it. On the same PC, you can run at the same time ARGO software and WSPR decoding software and see and upload the results of both modes.

Ferrite ring cores in the supply cable and also the audio cable.
All other cables have been removed from the PC.

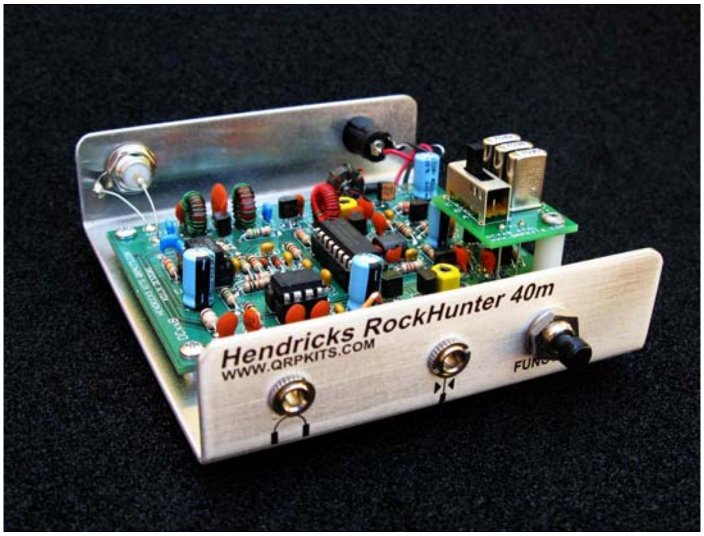
Interference suppression of the PC

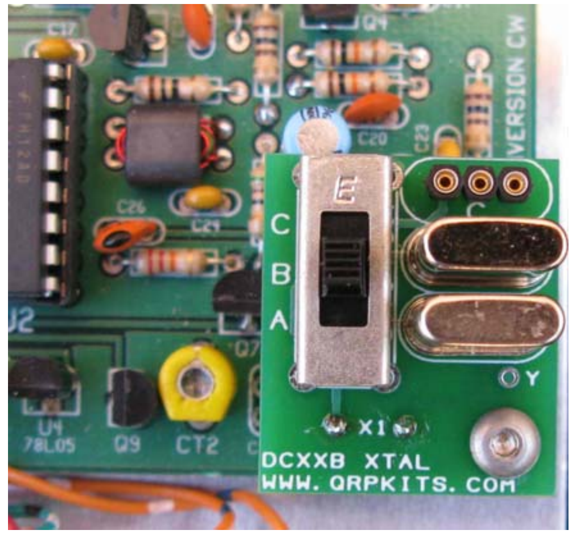
In the supply cable and the audio cable, ferrite ring cores were fitted to suppress the radio interference of the PC. All other cables were removed. The LAN cable has been replaced by a wireless WLAN connection.

The antenna, Could be better...

BACK TO THE INDEX PA2OHH

Hendricks RockHunter CW Transceiver w/switched crystal board assembly instructions



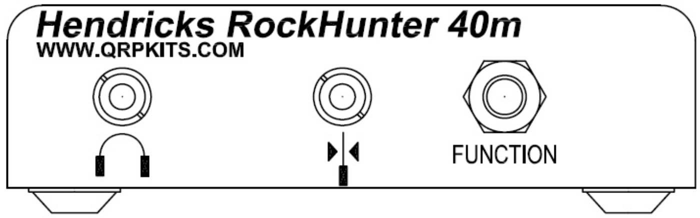


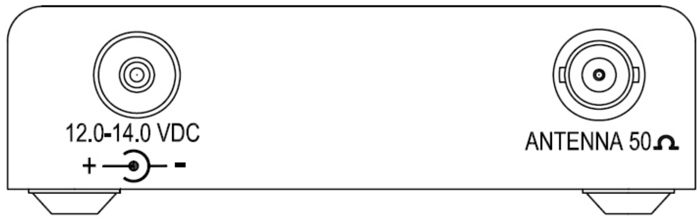
First off, check to see if the parts match the parts list…

1 – band specific additional crystal
1 – 3 pin SIP socket
1 – DP3T slide switch
1 – 4" - 20AWG tinned wire
1 – PCB
3 – 4-40 x 1/4" panhead screws
1 – 4-40 x 3/4" panhead screw
1 - #4 x 1/2" long nylon spacer
1 – BNC female chassis connector
1 – Push-in DC power connector
2 - 1/8" stereo chassis jacks
1 – push button switch
4 - rubber feet
1 – decal set
1 – aluminum chassis
1 lot – Teflon hook-up wire

Please read all the instructions before starting. You should only start using this set of instructions after you have completed and tested the main DCxxB board. These instructions cover the multi-crystal board and mounting to the RockHound open chassis.

Most of the assembly is done inside the chassis. So now, you need to prepare the chassis with the decals, using the picture below as a guide.





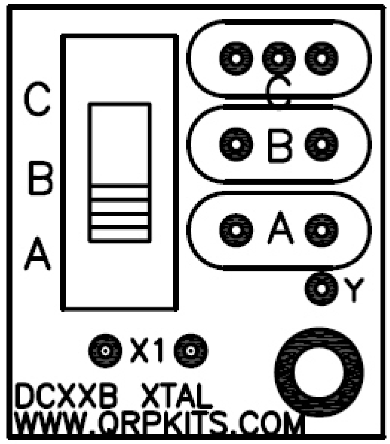
Thoroughly clean the surface of the panel to remove any oils or contamination. If you do not paint your case, we have found that moving the decals into position on a bare aluminum chassis is more difficult, due to the brushed surface, so we advise pre-coating the chassis with a light coating of the Krylon clear before applying the decals.

The decals are applied the same as model decals. Cut around each group of text you wish to apply. It doesn't have to be perfect as the background film is transparent. Apply the decals before you mount anything to the chassis. Use the above picture to get the correct spacing around the holes, as it is very easy to do a great decal installation and have a portion covered up with a knob.

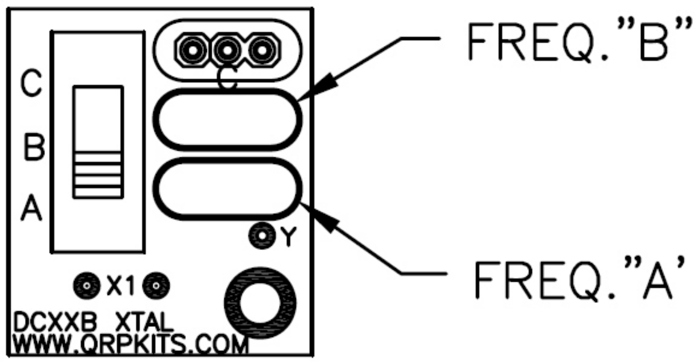
Trim around the decal. After trimming, place the decal in a bowl of lukewarm water, with a small drop of dish soap to reduce the surface tension, for 10-15 seconds. Using tweezers, handle carefully to avoid tearing. Start to slide the decal off to the side of the backing paper, and place the unsupported edge of the decal close to the final location. Hold the edge of the decal against the panel, with your finger, and slide the paper out from under the decal. You can slide the decal around to the right position, as it will float slightly on the film of water. Use a knife point or something sharp to do this. When in position, hold the edge of the decal with your finger and gently squeegee excess water out from under the decal with a tissue or paper towel. Work from the center, to both sides. Remove any bubbles by blotting or wiping gently to the sides. Do this for each decal, and take your time. Allow to set overnight, or speed drying by placing near a fan for a few of hours. When dry, spray two **light** coats of matte finish, Krylon, clear to seal and protect the decals, and allow the spray to dry in between coats. All decals come with two complete sets, in case you mess one up.

Allow plenty of time for the clear spray to harden up, and continue as follows:

- Install the DP3T switch on the side of the PCB with the silk screening.

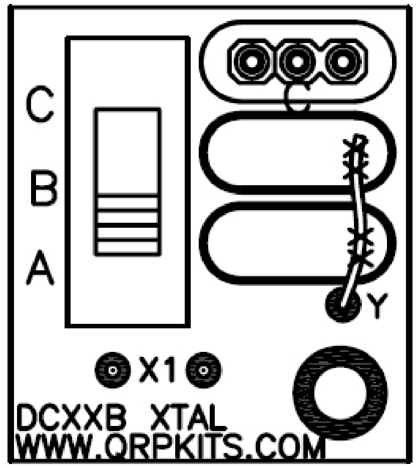


- Decide which frequency you want to be designated as “A” and “B”. Solder the crystals on the same side as the switch. Solder the 3 pin SIP strip into the “C” position.

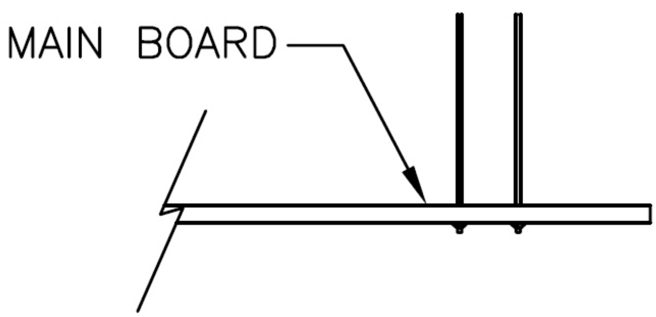


- It is common practice to tie all the crystal cases to ground. Note: you may choose not to do this operation if you plan on changing crystals frequently. Do not linger soldering the tinned wire to the crystal cases. The crystals are fairly tolerant, but they can be damaged by high prolonged heat. Cut a 2”” piece of the supplied tinned wire.

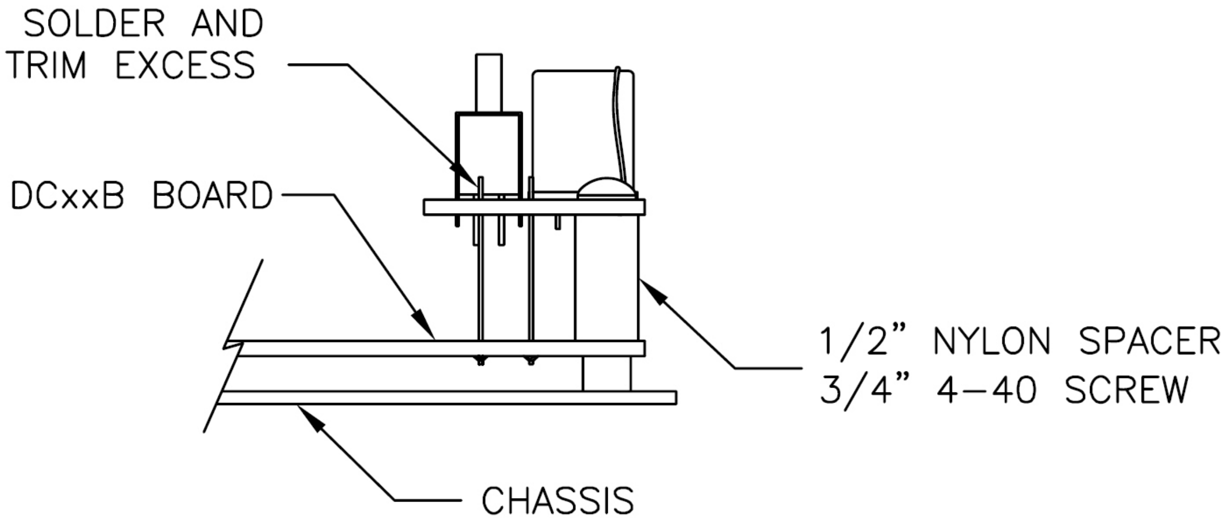
After soldering the wire to the top of the crystals, the wire passing through the “Y” hole can be soldered and trimmed off flush on the far side.



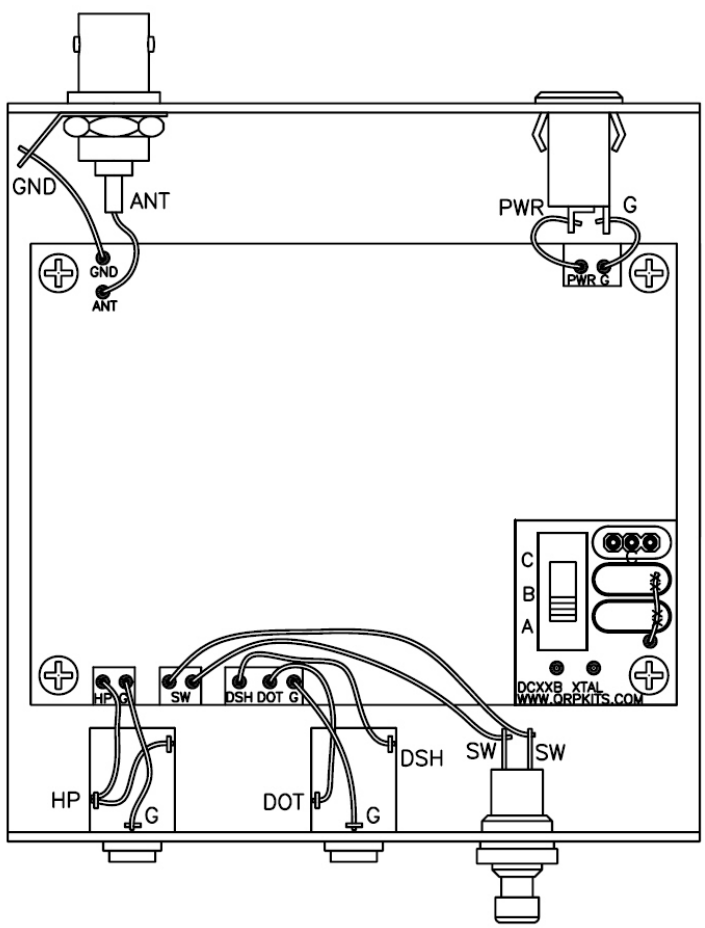
- If you installed one of the crystals, on the main board X1 position for testing, you will need to remove it now. Next you need to cut 2 pieces of the tinned wire, 3/4” long and solder them to the “X1” holes on the backside of the board, extending to the top of the board as shown. These leads will connect the expansion board to the X1 crystal position of the main board.



- Mounting of the expansion board to the main board is accomplished by first mounting the DCxxB board to the chassis and securing it with the three 1/4” 4-40 screws, leaving the front/right screw out. Slide the expansion board over the two X1 jumpers and secure the expansion board with the 3/4” long 4-40 screw with the 1/2” nylon spacer in between the two boards. Finally solder the two jumpers to the expansion board and trim flush with the top of the expansion board.



- You may now finish the interconnections from the main board to the connectors on the open chassis as shown below. Be sure to jumper the audio connector as shown so both sides of the earbuds will get sound.



rockhunter_050412.pdf

New 50 kW Ampliphase AM Transmitter

This article was published by RCA in Broadcast News, Vol. No. 111, June, 1961.

It describes the newly introduced BTA-50H 50 kW AM Broadcast Transmitter.

FIG. 1. Here is the new Ampliphase transmitter, type BTA-50H. Four compact cabinets occupy only 75 square feet of floor space.

NEW | 50 KW AMPLIPHASE

AM TRANSMITTER

Type BTA-50H Combines High Performance and Reliability with Low Operating Cost

Introduced in 1956, the *Ampliphase* concept is now proving its value in over 20 of the nation's top stations. Early this year a new model of the *Ampliphase* transmitter, type BTA-50H, was introduced. The BTA-50H has been installed in several stations where its performance is proving even better than previous models. This new transmitter offers several distinct advantages; such as, new lightweight PA tubes, improved driver tubes, silicon rectifiers, and an extremely stable exciter. In addition, each new *Ampliphase* transmitter is being completely tested at the factory to assure proper operation upon installation at the station.

The Ampliphase Transmitter

In the *Ampliphase* system RF is generated in the 807 crystal oscillator stage at carrier frequency. This signal is then amplified and separated into two channels differing in phase by 180 degrees. Each signal is then passed through d-c modullator stages adjusted to produce a phase difference of approximately 135 degrees between the two channels. Modulation is applied to each rf channel by a variable resistance type of phase modulator. The outputs of the modulated stages are then fed into amplifier stages using type 1614 tubes which in turn drives class C amplifiers using 4-250 tetrode tubes. The output from the 4-250 stage in each channel drives a 4CX5000A tube which in turn drives the final amplifier tube, type 6697, to well over 25 kw output in each channel. Each power amplifier has a conventional pi-network type of tank circuit with a common output shunt element. The combined output capability of the two power amplifiers is well in excess of 50 kw. A completely shielded two section low pass filter is incorporated in the output circuit in conjunction with two series-tuned shunt

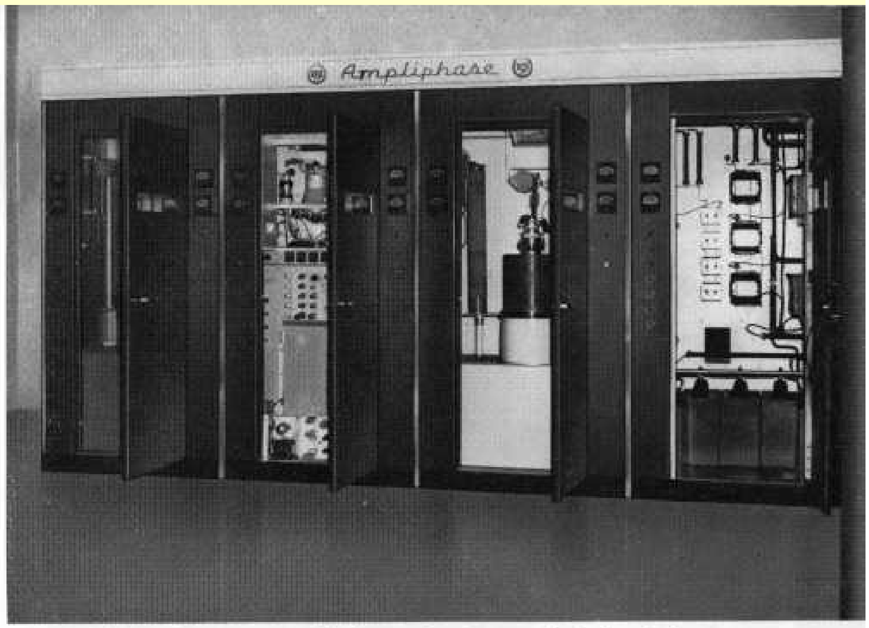
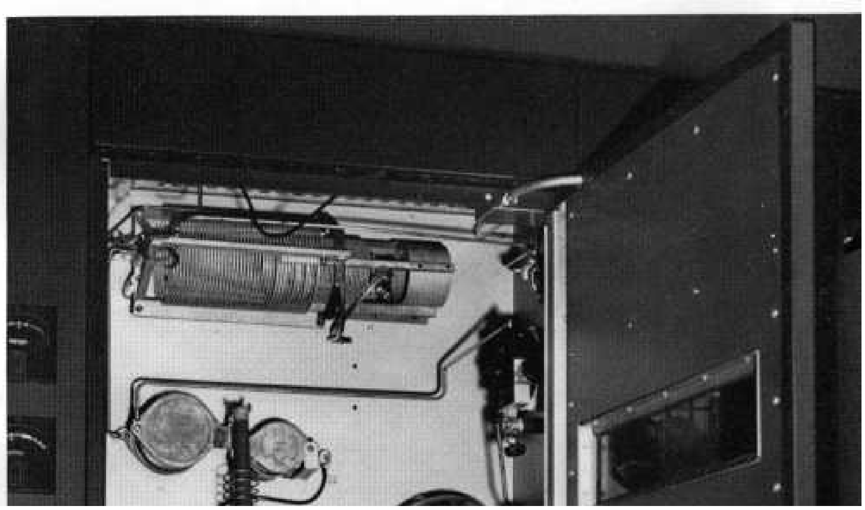


FIG. 2. Easy access to all tubes and tuning controls is through the front doors. The cubicle on far right contains the new silicon rectifiers, next is one of the PA stages. On the far left the other PA stage and next to it the exciter and driver stages.

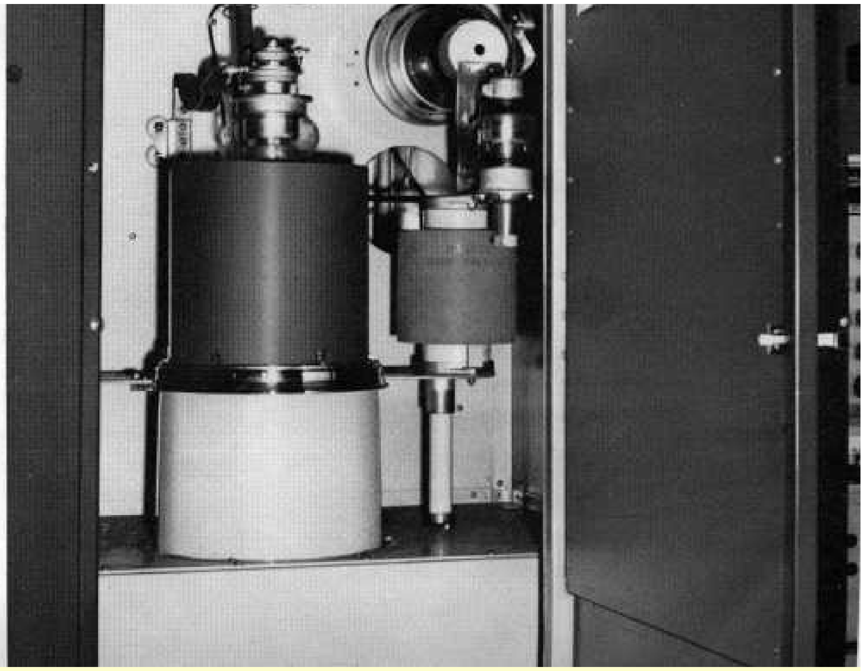
FIG. 3. Close-up of the new PA stage. Note the new lightweight 6697 tube.



connected traps which provide sufficient filtering action to easily meet or exceed present FCC requirements.

Improved Power Tubes

A single 4CX5000A ceramic, air-cooled tube is used in each driver stage of the two rf channels. The 4CX5000A tubes are operated well below their maximum ratings to provide long, trouble-free operation. A single type 6697 tube is used in each power amplifier in the two rf channels. The type 6697, rated at 35 kw plate dissipation, is required to dissipate approximately 14 kw under average modulation conditions, thus assuring long tube life. Because of the small physical size of the 6697 (actual weight 29 lbs.), one person can easily and quickly replace this tube.



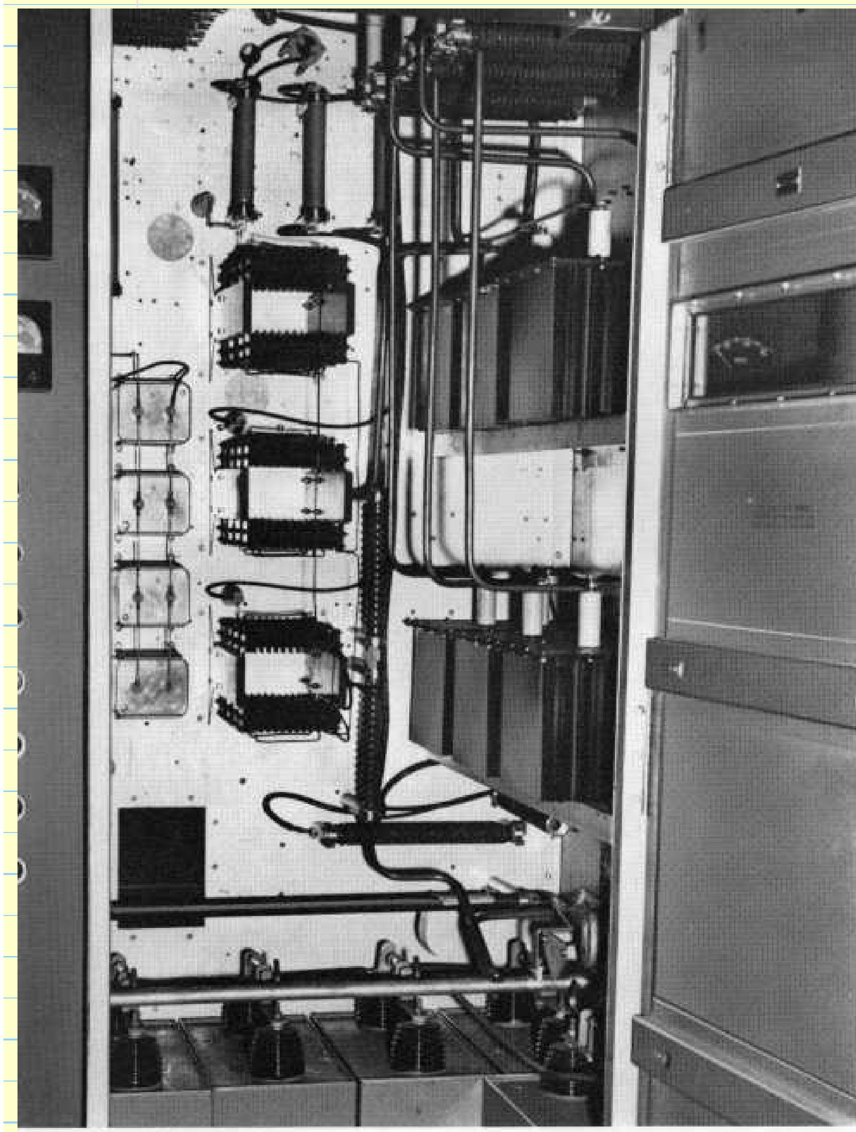


FIG. 4. The new silicon rectifiers are mounted vertically inside the cubicle. Filter capacitors are at the bottom of the cabinet.

Finest Sound

Low audio requirements in the *Ampliphase* system eliminates the need for large costly transformers, reactors, and modulator tubes. Extended range frequency response is easily attainable. The high modulation capability of the *Ampliphase* system means a louder sounding signal and improved coverage.

Solid State Rectifiers

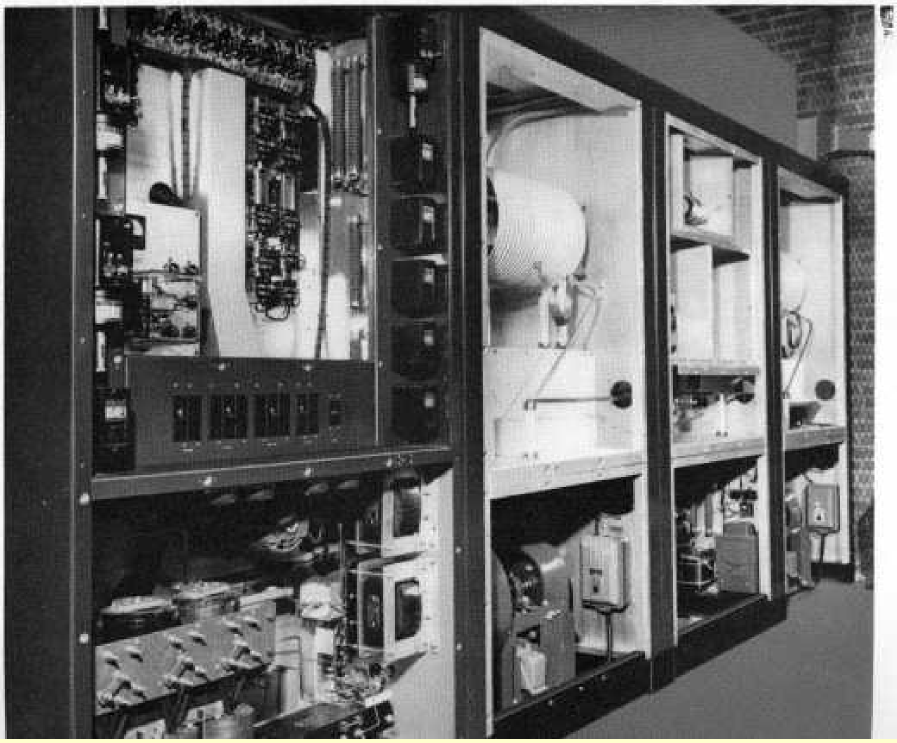
Silicon rectifiers are used in all high voltage, bias and low voltage power supplies in the BTA-50H. The high voltage plate supply rectifiers are immersed in oil to eliminate corona and other environmental hazards. Solid state rectifiers permit the transmiter to operate in ambient temperatures as low as —20 degrees centigrade which makes remote operation in unheated buildings feasible.

High-Speed Overload Protection

Two types of overload protection are used in this transmitter. The current types (instantaneous and time delay) are connected directly in the tube circuits and rectifier ground leads. Thermal magnetic circuit breakers are used as back up protection and as disconnect switches. The transmitter circuitry is arranged so that an overload will either lock out the plate supply circuit or allow a single reclosure that will reset if there are no further overloads. In either case, when a lockout position has been reached, the overload circuit can be reset by means of an overload reset con-

FIG. 5. Rear access to the BTA-50H is very easy. Rear

panels are removed to permit servicing and maintenance.



trol. Principal overload relays are equipped with indicating flags that indicate which overload relay has operated even after the overload has cleared. A reflectometer is installed in the output transmission line which offers automatic protection should greater than normal change in load occur.

Ideal For Remote Control

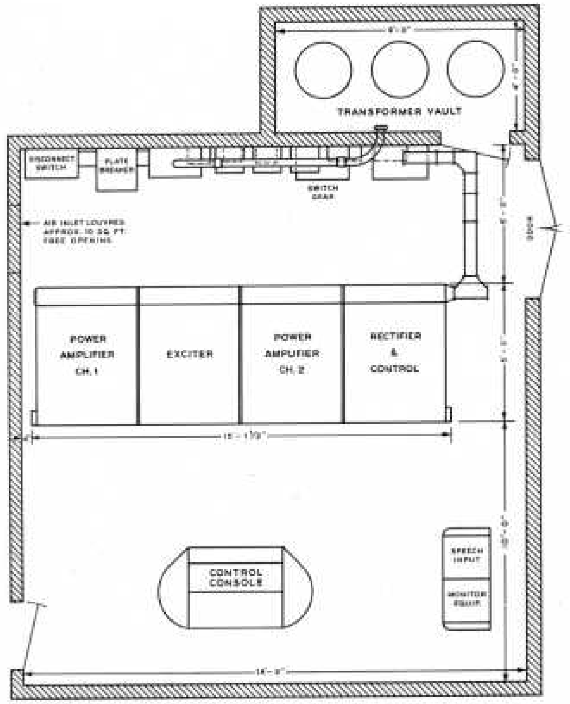
All BTA-50H metering and control facilities are terminated in convenient locations to permit straight forward wiring to remote control units. Auxiliary functions, such as remote control switching to a stand-by transmitter, dummy load, auxiliary power supply, etc., can be furnished.

Minimum Building Requirements

Outstanding among the features of the *Ampliphase* transmitter is the small floor space required (see floor plan, Fig. 6). Compactness without sacrificing accessibility is a space saving feature of the BTA-50H transmitter. In fact, the BTA-50H occupies no more space than older 5 and 10 kw transmitters.

Tuned and Tested On Frequency

Each BTA-50H Transmitter is assembled and tested on the customer's frequency prior to shipment. Most components are shipped installed in the transmitter cabinets resulting in reduced installation time. Complete measurement data including meter readings and dial settings obtained during factory test are supplied to the customer. This results in a simplified tune up procedure after installation.



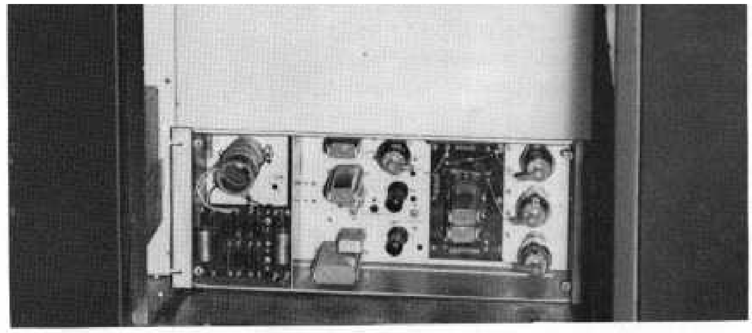


FIG. 7. The drive cabinet shown here contains (from top to bottom): the 4CX5000A driver stage, the 4-250A stages, the exciter modulators, and at the bottom the crystal oscillator.

FIG. 6. The typical floor plan shown here is ideal for operations with an operator on duty; however, if remote control is used the building requirements can be greatly reduced.

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7/26/00

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MK484 MW Receiver

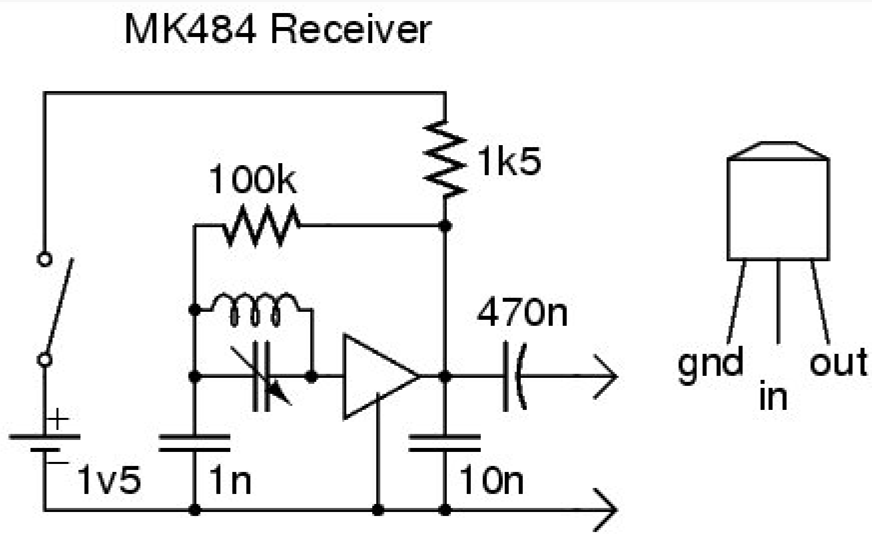
2007-03-24

I've grown tired of my

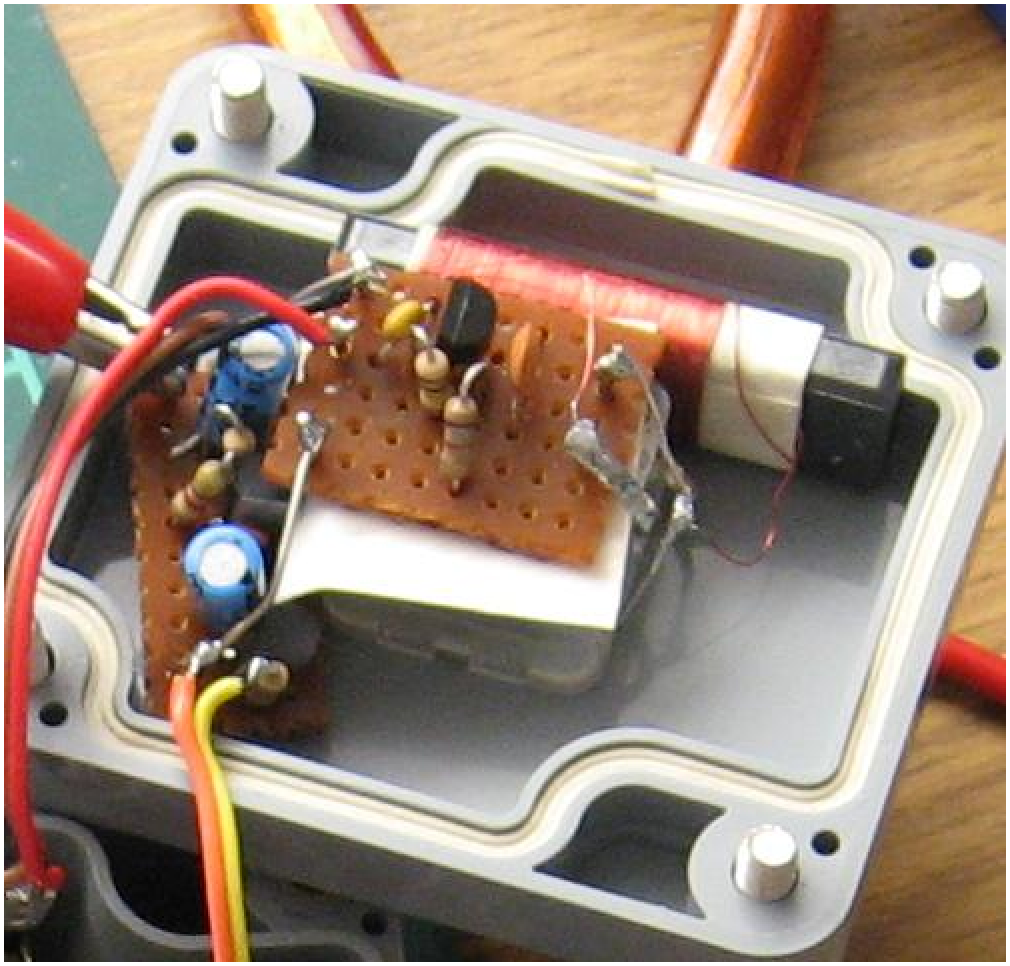
regenerative AM broadcast receiver's lack of AGC and its RFI problems, so I decided to build something based on the MK484. I've had them laying around for years in the junk box, and my recent work in using them for an AM receiver IF prompted this project.

Other requirements for this project were a small size, something smaller than the current plastic tub I carry in my backpack to work every day, and something with a calibrated tuning dial to take the guess work out of tuning. I also set myself a challenge to build it using only a single 1.5 volt cell for the supply, and driving conventional 32 Ohm dynamic earphones.

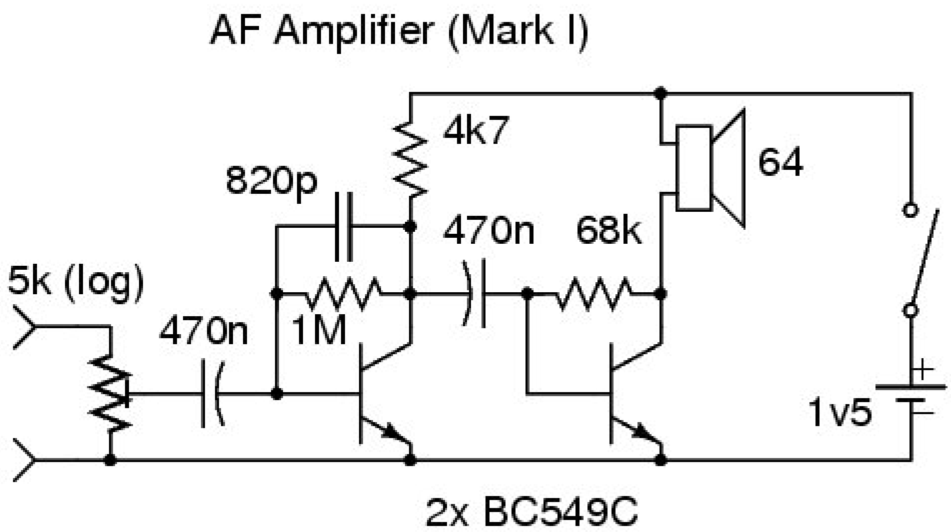
The RF section is very simple, basically the single cell "reference design" MK484 receiver. The ferrite rod is the small rectangular prism unit available from Jaycar or Electus (catalogue number LF1016), I measured its mu-rod at about 65 and calculated the turns required for 400-450 uH or so, required to cover the extended AM broadcast band completely using the 165 + 62 pF tuning gangs also available from Australian electronic stores.



The RF circuit was constructed on a small scrap of veroboard and connections made between it, the rest of the components using PCB pins. At this point the smallest grey ABS box from Jaycar was selected as the enclosure and the polyvaricon tuning gang mounted in the middle of the lid. A knob was selected, large enough for good feel, but small enough to allow a well marked dial to be added later. The adapter hardware from Doug Hendricks KI6DS QRP Kits was again used to mate the polyvaricon with the 1/4" grub screw retained knob. The RF board was "mounted" with stiff wire on the back of the polyvaricon after its trimmers were set for minimum capacitance (a piece of cardboard insulating the track side), and the tuning range customised by removing several turns on the loopstick until it covered from about 538 kHz to 1791 kHz - my overshooting the inductance no doubt a result of the distributed capacitance of the windings. The windings were fixed in place with wax using a candle and the heat gun. The loopstick was then secured to the underside of the enclosure lid with two blobs of 2-part epoxy.

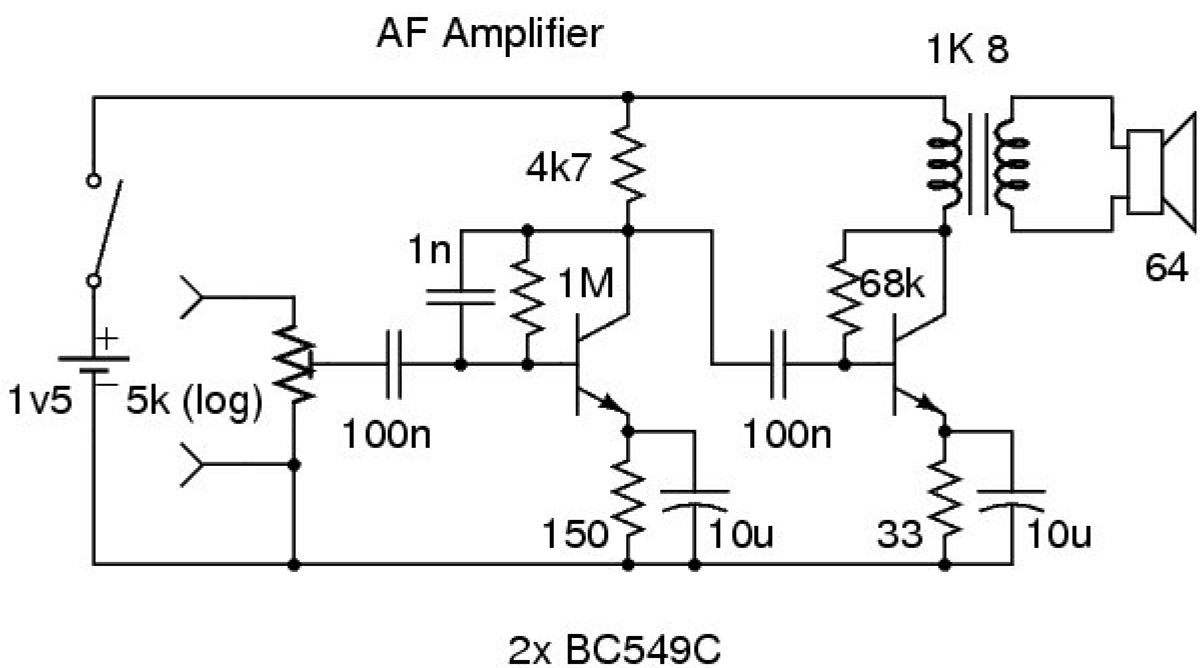


With the RF side of the receiver complete, now came the more challenging bit, an AF amplifier of reasonable performance powered by only a single cell. There have been many "optimised" single-cell headphone amplifiers published over the years, most of them heavily using boot strapping and being quite complex with lots of transistors and large value electrolytic capacitors. I had no where near enough room to fit such a design, so at first I went with a classic two transistor line up that fits on a 4x10 hole piece of veroboard.

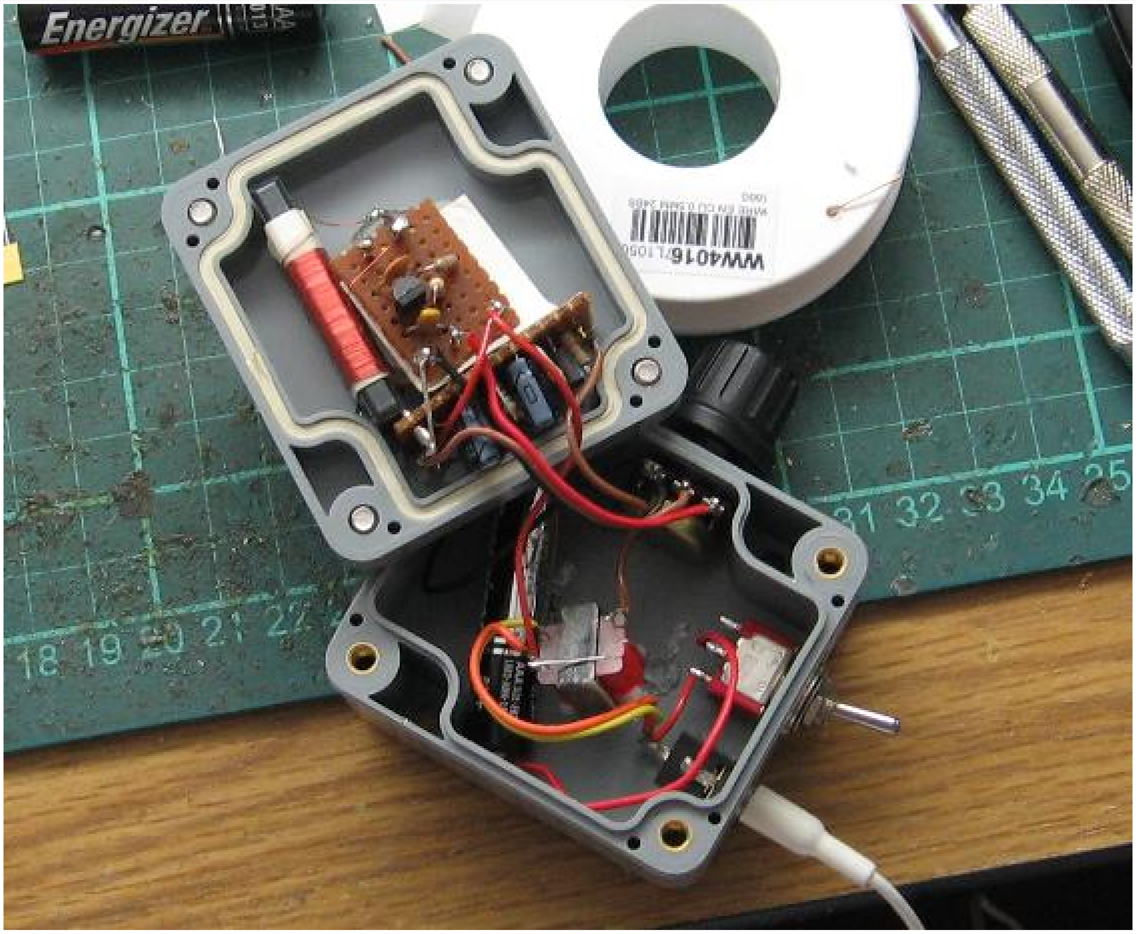


In this circuit DC passes through the speakers, and despite some careful design to improve its performance compared to the similar circuit in the Regenerative FM Receiver, I found its performance fairly poor. It offers sufficient gain and undistorted output for a quiet room, but it is completely unsuitable for the kinds of environment I wanted to use the radio in, on my daily commute to work. Its response rolls off at about 15-18 kHz, and the LF corner is quite good due to the largish coupling caps. From 3 volts up, such a circuit is quite usable. If you put a 1K:8 Ohm transformer in the final collector circuit and modified the feedback a little it might actually offer quite acceptable performance.

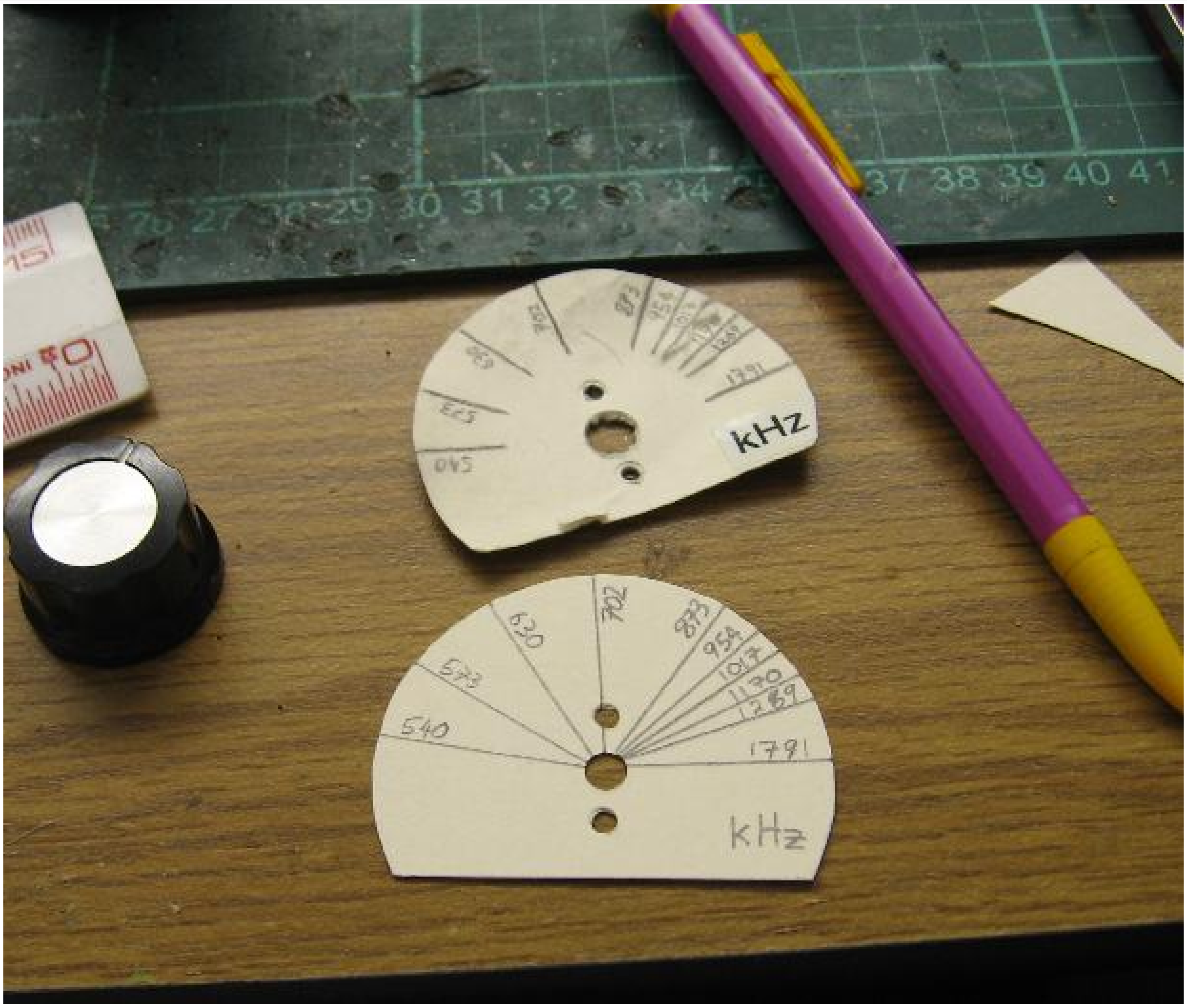
After using the radio with this Mark I AF amplifier, I decided to modify it for better performance. I picked a transformer coupled circuit to get the best output possible with the low supply voltage. Unfortunately this meant replacing the AA cell with an AAA cell to make sufficient room for the audio transformer.



The emitter resistor bypass on the final transistor is probably redundant, it varies the gain only slightly, you can omit it to save space if you wish. The emitter resistance is important to minimise distortion however. The LF corner is somewhat worse than the original circuit, and the HF response rolls off a little earlier, but the result sounds quite natural. Most importantly there is much more power gain available, delivering ear-bleeding levels at the onset of objectionable distortion.



The finishing touches were some labelling using a Dynamo label maker, and the creation of a nicely laminated dial for the tuning knob. I used the XYLs Xyron 510 machine to make a piece of cardboard into a sticky-backed label which was pasted into place. This was marked with the assistance of the signal generator (and off-air signals). This was then peeled off and a final version made using the original as a template. The final version was run though the Xyron machine again using a laminate cartridge to produce a very pleasing glossy result.



Notes

The wall of the plastic enclosure is too thick for the 3.5 mm stereo socket mounting thread. I ended up epoxying it into the wall. With some care I guess you could thread it into a slightly undersized hole, but gluing it right into the hole is much less mechanically challenging, especially if you didn't notice the problem until after you drilled the hole like I did!

As usual, a switched pot would avoid the need for a separate power switch. It would also make the radio more resistant to accidental turning on while it is knocking around in your bag. If only suitable switched pots were a still available from Jaycar or DSE...

The selectivity could be better, 2BL (702 kHz) is an enormous signal at my QTH and can be heard between channels near the centre of the tuning range. It is not all that objectionable, except when trying to chase DX at night - which was never a design requirement. I probably should have used Litz wire for the coil, or tried using one of the commercial pre-wound coils (like Jaycar catalogue number LF1020). Such coils are designed to match the tuning gang I am using, but past experience has suggested their precision leaves a lot to be desired, often being incapable of tuning the entire band even when moved physically on the ferrite bar and using the trimmers on the tuning gang. They are a cheap source of an approximately correct coil that can be tweaked though.

A Q-booster using a simple FET circuit could tighten the selectivity, but it would chew more power and isn't really required for local station work. I am just being picky really, the performance as-is exceeds most bargain-store superhets.

The Xyron 510 machine is a damn handy piece of kit. It can place adhesive on the back of any thin, fairly flat, object, or laminate both sides, or one side and put adhesive on the other. Cartridges are available with a choice of re-positionable or permanent adhesive, it can even make fridge magnets. Its main target market is the scrap booking community, but homebrew electronic hobbyists would find it very useful for panel work.

6 comments.

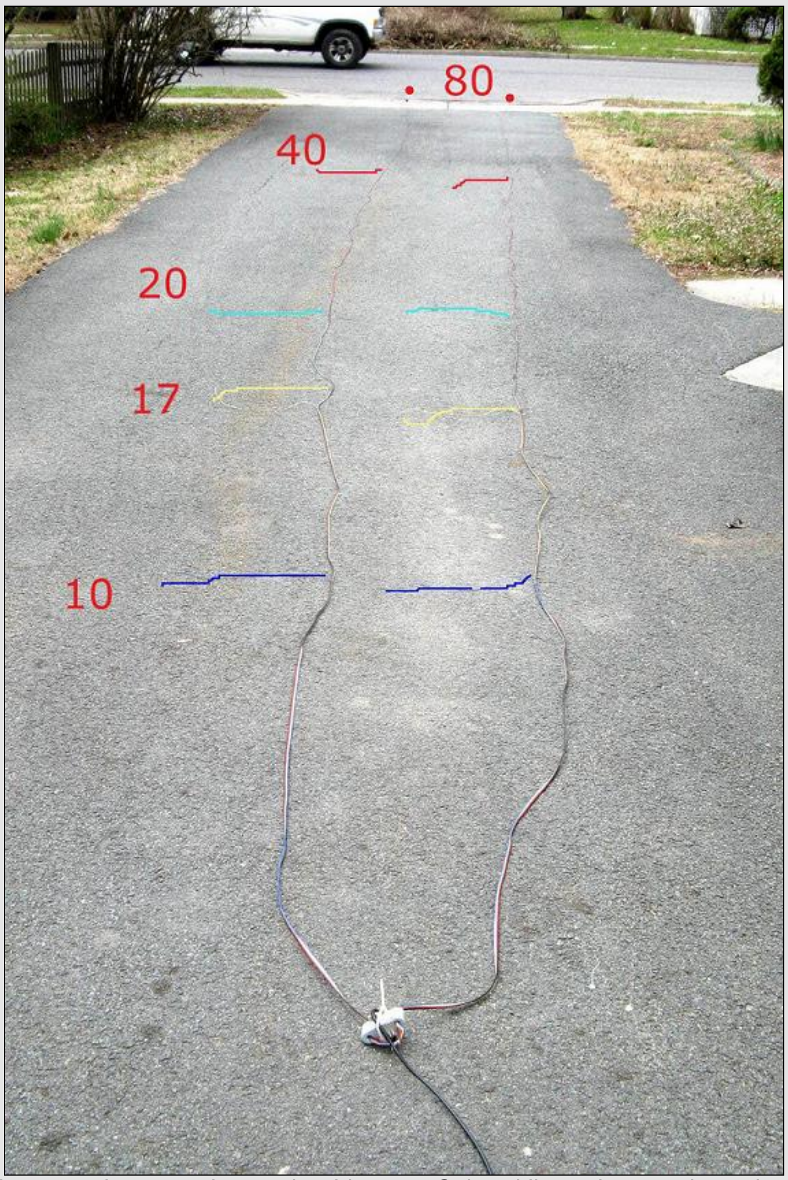
Attachments

title	type	size
RF Board Circuit Source	application/postscript	13.346 kbytes
AF Board (Mark I) Source	application/postscript	13.053 kbytes
AF Board (Mark II) Source	application/postscript	14.849 kbytes

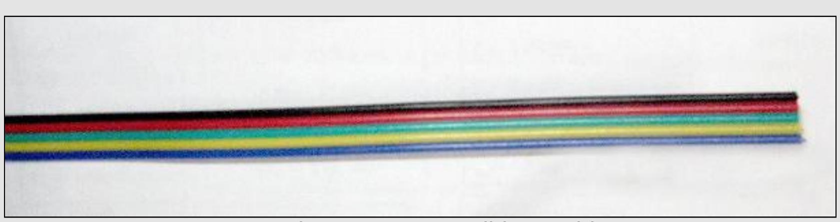
hamuniverse.com

N4JTE 6 BAND "RIBBON" ANTENNA $35

This antenna article is geared towards new Hams and antenna builders looking for a very inexpensive 6 band antenna that can be efficiently fed with 50 ohm coax without a tuner.
The inspiration for this design resulted from a visit to my 82 year old neighbor's home who had asked me for some help in dismantling his amazing and extremly beautiful model train set, and box up for his grandson. During this process I was intrigued by his use of 5 and 10 conductor 18 gauge flat insulated ribbon cable for all of the L.V. switching and action devices.
So Begins the Adventure.......



Antenna shown resting on the driveway. Colored lines show each section.


5 conductor computer ribbon cable

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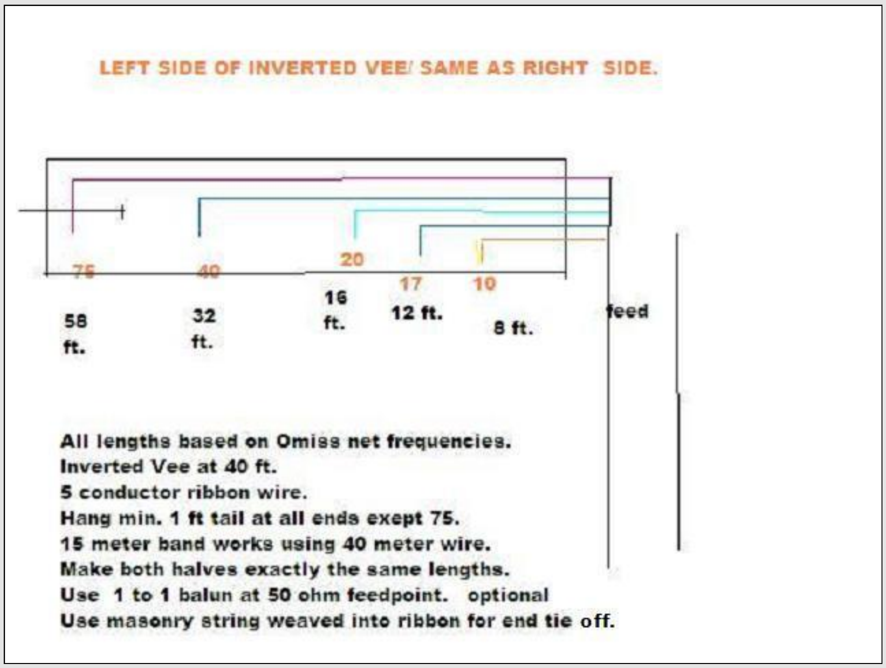
To be honest I am getting more and more frustrated with some of the latest marketing ploys being used by commercial antenna manufacturers and their incredible, misleading and unsubstantiated miracle "all band" antennas that will sucker in some poor unsuspecting new ham who will spend his money on a heavily marketed, over priced, and in some cases, amazingly reviewed antenna // Toaster.
My plan was to use this relatively cheap insulated wire and find out if was actually possible to get 6 bands cleanly matched to 50 ohm coax. As this antenna was basically built for testing and performance evaluation the construction details are limited and somewhat primitive by most standards so I will leave it to others to refine, hi. When I envisioned this concept my only real concern was how all the close spaced wires would interact. The shorter dipoles will all present high impedance at the feed point when they are not driven forcing the feed line to pick the path of least resistance and best match for the frequency.

The 40 meter wire will serve well on the 15 meter band as a center fed 1.5 wl wire.
I am aware that a fan dipole uses the same single feed concept but I believe the ribbon antenna eliminates all those extra tie off points while maintaining the resultant extra effective radiated height, especially if used in a flat top configuration. Certainly less obtrusive and much less work. Below is the basic layout with lengths for each half of the dipole.



Final lengths per side of each dipole:
75 meter length 58ft

40 meter length 32ft (also used on 15 meters)

20 meter length 16ft

17 meter length 12ft

10 meter length 8ft

Well you have to start somewhere, so I chose the [OMISS net frequencies](http://omiss.net/) available at http://omiss.net/, as my starting point for the band frequencies and wire lengths.
I have built more than enough monoband Inv. Vees at this location with insulated wire so I use my own formula of 450/ freq, to achieve what I'm after with minimal pruning.

You need to approach this antenna one side at a time. The ribbon wire I purchased was only available in 50 ft. lengths so I knew the 75 meter wire would need about 8 more feet added to each end to reach 75 meters. It's best to unroll and stretch the wire out to remove the "wire memory".

With that accomplished, measure out your 5 chosen 1/4 wl lengths and mark or tape

off.
As the 75 meter wire is pretty much done after adding the required wire, separate the next wire, and carefully peal back to the taped off marker and cut off excess. Continue this process for the remaining wires up to the 10 meter point. Yeah I know it seems like a lot of wasted wire but at 6 cents a foot you'll get over it !

Repeat the process with the other half of your antenna. I just laid them along side each other and matched all the lengths. Be careful to use a dull knife or fingernail file to separate the wires so as to not break the insulation.

After cutting all your wires to length you will need to have some kind of center support and feedline connector in mind before stripping and soldering the 5 conductors together. In my case I pushed each one thru a ceramic insulator and then carefully stripped and soldered together in preparation for feedline attachment.

The ends of half wave dipoles are at high rf voltage and if too close to others will add unwanted capacitance and tuning problems. For starters I just separated the adjacent wires by about a foot and let them dangle down.

FIRST ATTEMPT.
My goal with this initial attempt was to see basically where or if, I would get full power out. This would give me the best indication of what was actually radiating and at what frequency. You cannot expect, nor limit yourself, to a 1 to 1 swr as being your goal.
The meter will serve only as a guideline to where your wire length and height works in the real world of your backyard.

A quick look at any antenna book will show the relationship between height above ground and radiation resistance in ohms. This inv. Vee at 43 ft. is even a little more tricky to predict especially when the 75 meter antenna is only at .175 wl high and the 10 meter antenna is at 1.2 wl above real ground.

All 6 antennas (the dipoles) should range between 20 and 90 ohms with the ends at 10 ft. above ground. The results of the first attempt were very interesting in that at least I was getting full power out somewhere close to the 6 bands of interest.
I had my doubts because of introducing the 17 meter antenna into the mix which is not an even multiple of the lowest band, usually considered a no no on multiband antennas.

--
SECOND ATTEMPT:
I use an eye hook stuck into the top of the fiberglass pole with a masonry string to allow easy up and down access for the cutting and tuning process.
I started by adding about 4 ft to each end of the 75 wire and after some diddling ended up with around 3.95Mhz. The only band affected by this change when scanning thru the bands was the 40 meter wire which changed it's apparent resonant frequency to 6.9Mhz and the 15 meter wire also dropped in frequency.
A quick trip to the backyard to shorten each end of 40 meter wire by one foot made no change on the resonance. I then separated the 40 from the 75 by dangling about 3 ft. at each end. Obviously the end effect was kicking in because I ended up at 7.1Mhz, close enough for my needs and the 15 meter wire was happy in the middle of the SSB portion.

FIRST TRY RESULTS
75----------4.179Mhz short
40----------7.290Mhz short
20----------14.190Mhz okay
17----------17.800Mhz long
15----------21.553Mhz long
10----------27.713Mhz long

SECOND TRY.
75--------------3.95Mhz
40--------------7.1Mhz
20--------------14.190Mhz
17--------------17.800Mhz
15.--------------21.300Mhz
10---------------27.717Mhz

THIRD ATTEMPT:
The only bands left to fine tune were the 17 and 10 meter wires which were still too long, so I cut off 6 inches from both ends of each antenna. The 17 meter ended up at 18.135Mhz and the 10 meter at 29.5Mhz in the FM portion of the band which I actually prefer these days.

THIRD, FINAL TRY, I'm lazy:
75----------------3.95Mhz
40.---------------7.1Mhz
20----------------14.190Mhz
17----------------18.135Mhz
15----------------21.360Mhz
10----------------29.500Mhz

RECAP:
The whole tune/recut exercise took about 6 hours and resulted in a 6 band antenna that will radiate full power out without a tuner.
Due to the fact that there are no traps, no loading coils, no tuners and no ladderline needing a balun to match, the only losses will be in the feedline due to it's length and not the result of any mismatch at the antenna feedpoint. I do not have the necessary brain power to model this design and would appreciate a peer review on the modeled radiation resistance and resultant antenna patterns.

Point of interest; The 60, 30 and 12 meter bands had around a 3 to 1 swr and were showing 60 to 70 watts out without a tuner. Probably will work well with an auto tuner.

IF YOU BUILD IT:
1. A simple Plexiglas T, or equivalent with double slots for the ribbon wire and two small holes to tie wrap the coax should be more than enough after waterproofing to ensure stability and strength for a center supported light weight antenna such as this.
2. The 75 meter wire ends up holding the whole antenna up, so I would attach some masonry string to the center insulator and tie wrap at the dipole leg end dangles and a couple more at the 40 and 80 wires with the string going to tie off points. By tie wrapping you will also prevent the wires from separating at band junctions.
3. Attach small non conductive weights at the drop wires after final tuning.
4. Use a tuner at higher powers to attenuate harmonics and any possible spurious transmitter outputs.
5. If 10 conductor wire is available you can double up the wires for each band providing an increase in bandwidth and power handling. FYI, I had no problems with the 5 wire at 500 watts ssb.

FINAL COMMENTS:
I am not going to waste everyone's time by recounting all my log entries while testing this antenna. I will tell you it is a joy to run from 75 to 10 meter fm and be able to hear what is going on and respond to a cq without fumbling around with antenna switches and tuners. This antenna is nothing more than 6 inv vees at 43 ft. that perform to the laws of physics and will serve you well if you are committed to a little sweat equity to get it working efficiently.

You will not be disappointed with this $35 antenna.
BUILD.... DON'T BUY !
Tnx for reading,
Bob N4JTE

RF circuit design: Basics

Akira Matsuzawa

Tokyo Institute of Technology

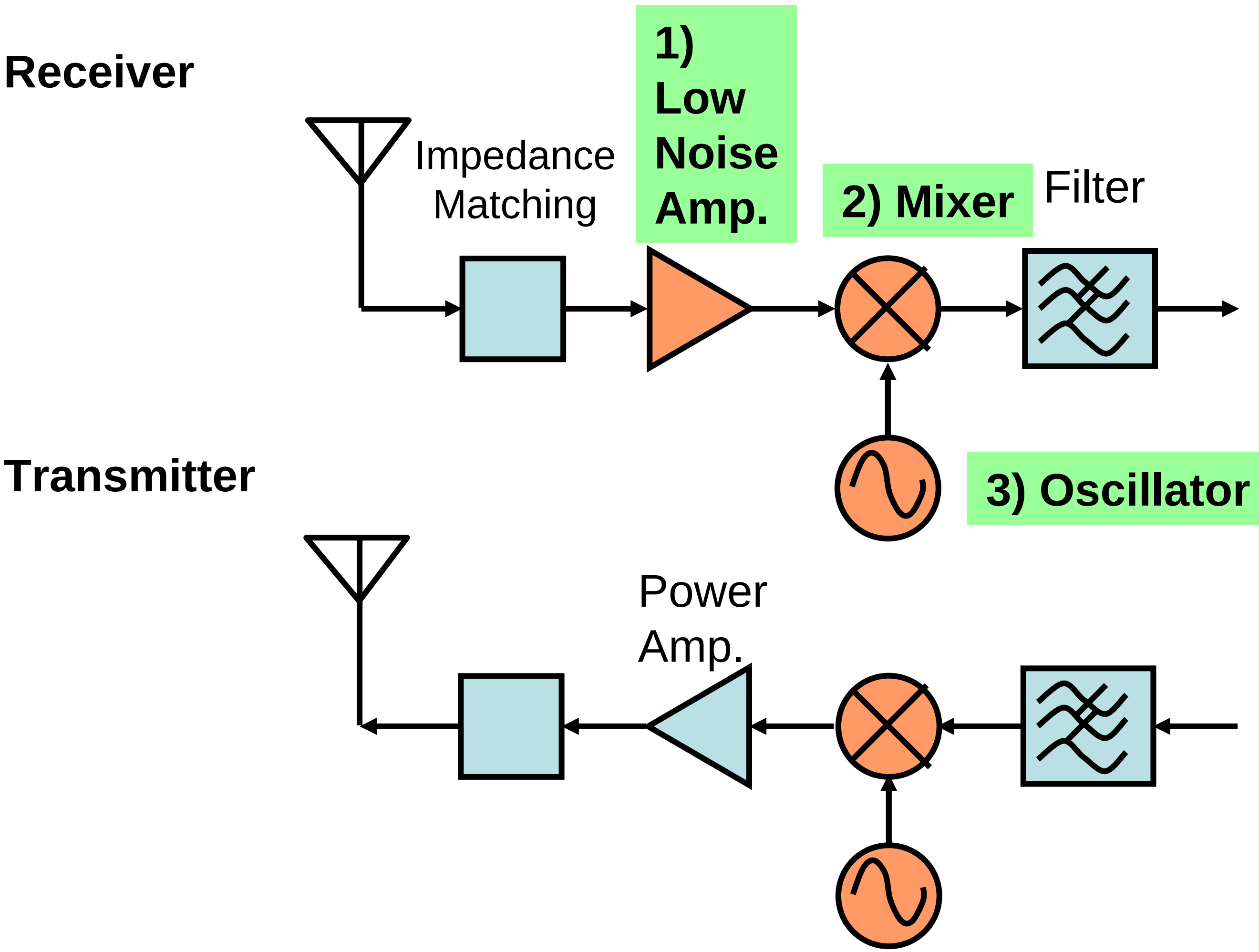
Contents

- Building blocks in RF system and basic performances
- Device characteristics in RF application
- Low noise amplifier design
- Mixer design
- Oscillator design

Basic RF circuit block

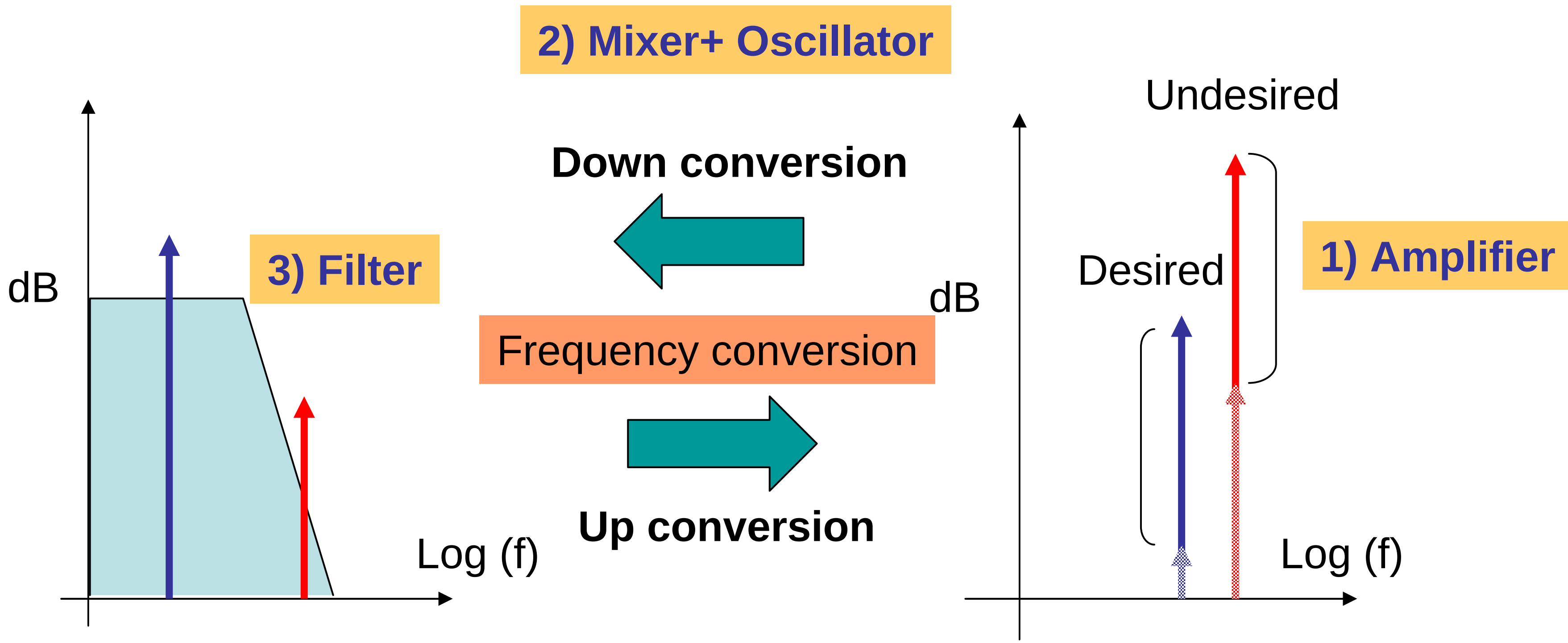
RF systems are composed of limited circuits blocks.

LNA, Mixer, and Oscillator will be discussed in my talk.



Basic functions of RF building blocks

Amplifier, frequency converter (mixer +oscillator), and filer are basic function blocks in RF system.



RF Amplifier

- **Gain:** Amplify small signal or generate large signal.
- **Noise:** Smaller noise and larger SNR.
- **Linearity:** Smaller non-linearity.

Non-linearity generates undesired frequency components.

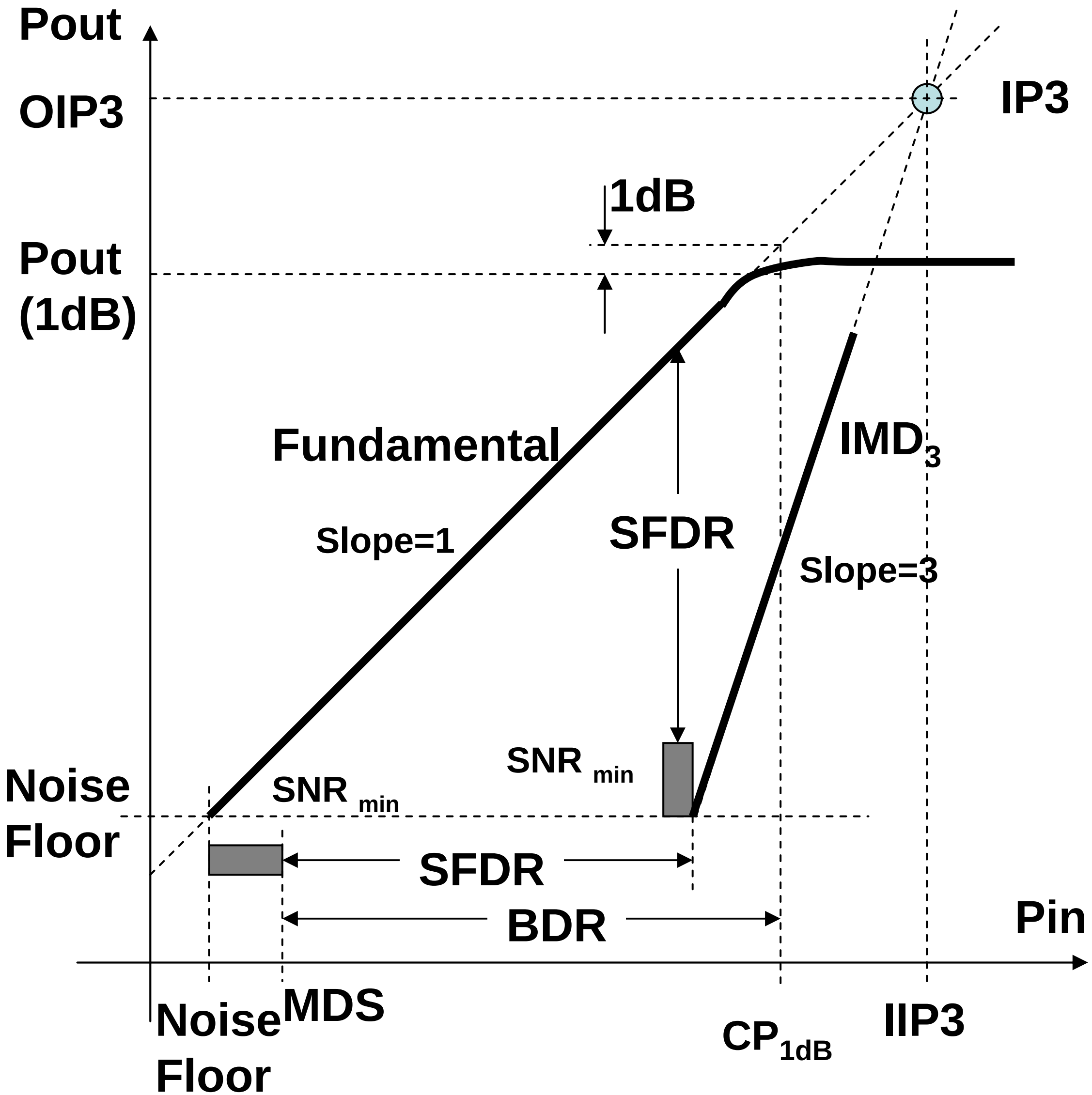
$$v_{out}(t) = \alpha_1 v_{in}(t) + \alpha_2 v_{in}^2(t) + \alpha_3 v_{in}^3(t) + ...$$

$$\left(\cos(\omega_1 t) + \cos(\omega_2 t)\right)^2 = 2 + \cos(2\omega_1 t) + \cos(2\omega_2 t) + \cos((\omega_1 - \omega_2)t) + \cos((\omega_1 + \omega_2)t)$$

$$\left(\cos(\omega_1 t) + \cos(\omega_2 t)\right)^3 = \frac{1}{2}\cos((2\omega_1 - \omega_2)t) + \frac{1}{2}\cos((2\omega_2 - \omega_1)t) + ...$$

Input and output characteristics

Distortion and noise are important factors in RF amplifier, as well as power and gain.



Dynamic range

$$Noise\ Floor = \underbrace{-174}_{\text{kT limitation}} dBm + NF + 10\log \underbrace{BW}_{\text{Bandwidth}}$$

SFDR: Spurious free dynamic range

The input power range over which third order inter-modulation products are below the minimum detectable signal level.

$$SFDR = \frac{2}{3}\left(IIP_3 - Noise\ Floor\right) - SNR_{\min}$$

BDR: Blocking dynamic range

$$BDR = P_{1dB} - Noise\ Floor - SNR_{\min}$$

MDS: Minimum detectable signal level= Noise Floor +SNR_{min}

Non-linearity

CP_{1dB}: The input level at which the small signal gain has dropped by 1dB.

$$CP_{1dB} = \sqrt{0.145\left|\frac{\alpha_1}{\alpha_3}\right|}$$

IMD3: The third order inter modulation term

IP3: The metric third order intercept point. It is the point where the amplitude of third order inter modulation is equal to the that of fundamental.

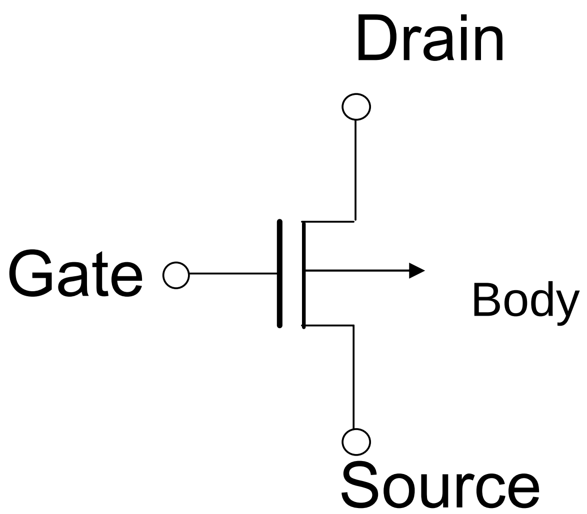
$$A_{IP3} = \sqrt{\frac{4}{3}\left|\frac{\alpha_1}{\alpha_3}\right|}$$

IIP3: Input referred intercept point
OIP3: Output referred intercept point

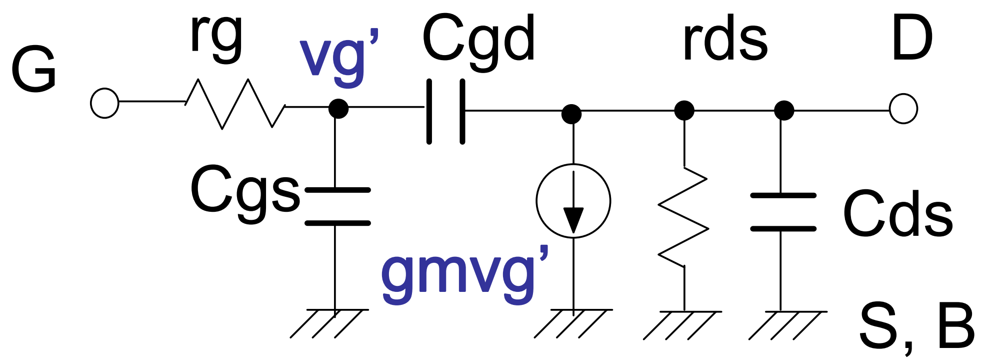
$$P_{out} - IMD_3 = 2 \cdot \left(IIP_3 - P_{in}\right)$$

MOS transistor

Intrinsic gate voltage and gm are the most important factors in RF CMOS.



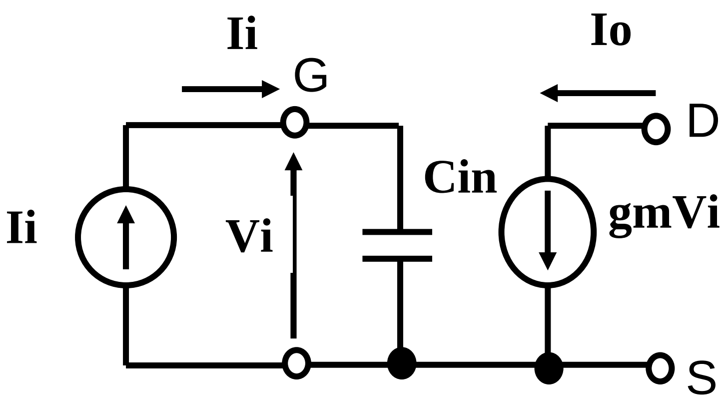
MOS Transistor



Equivalent Circuit

Cutoff frequency: f_T

For higher f_T, increase gm and decrease Cin.



f_T: Frequency at which the current gain is unity.

$$Ii = Iio\sin(\omega t)$$ Input current

$$Vi = \frac{Iio}{\omega C_{in}}\cos(\omega t)$$ Gate voltage

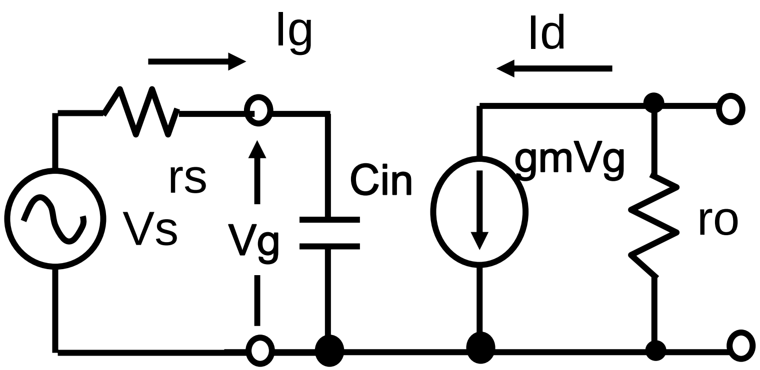
$$Io = gmVi = \frac{gmIio\cos(\omega t)}{\omega C_{in}}$$ Output current

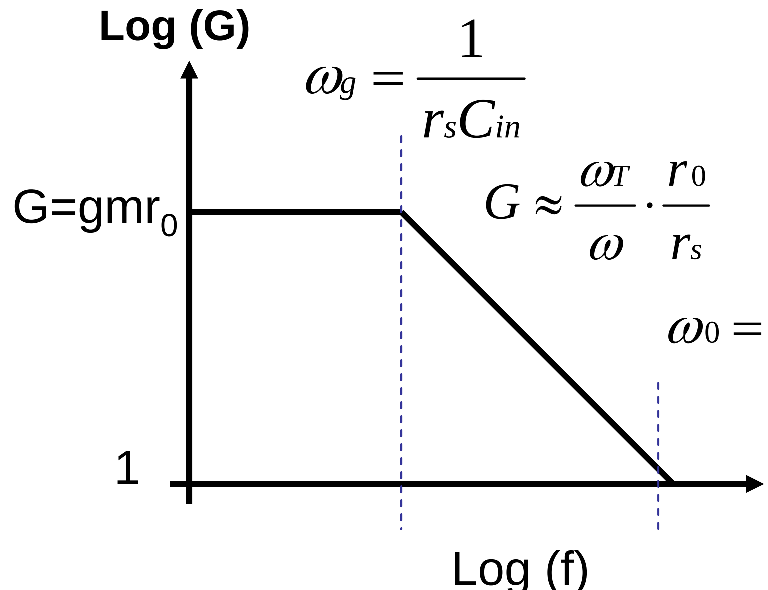
$$\therefore\ f_T = \frac{gm}{2\pi Cin}$$

Proportional to gm
Inversely proportional to Cin

Amplifier gain

For higher voltage gain, increase gm, f_T, ro (Q), and decrease input and gate resistance





$$\omega_g = \frac{1}{r_s C_{in}} \qquad \omega_T = \frac{gm}{C_{in}}$$

$$G \approx \frac{\omega_T}{\omega} \cdot \frac{r_0}{r_s}$$

$$\omega_0 = \frac{gmr_o}{r_s C_{in}} = \omega_T \frac{r_0}{rs}$$

For the larger gain

Fundamentally larger gmr_0 $G \approx gmr_o \approx \dfrac{I_{ds}}{\left(\dfrac{V_{eff}}{2}\right)} \cdot r_o$ ⇒ Larger I_{ds} or r_o

Larger Q

Higher f_T and lower r_s

V_{eff} is difficult to reduce $\quad \because r_o = Q\omega_0 L = \dfrac{Q}{\omega_0 C}$

→ Distortion and C_{in} increase

Characteristics of gm (Basic)

Gm is proportional to the Ids and inversely proportional to the V_{eff}.

V_{eff} is proportional to square root of I_{ds} and inversely proportional to square root of (W/L) ratio.

Square law region

$$I_{ds} = \frac{\mu C_{OX}}{2n}\left(\frac{W}{L}\right)(V_{gs} - V_T)^2 = \frac{\mu C_{OX}}{2n}\left(\frac{W}{L}\right)V_{eff}^{\;2}$$

$$gm \equiv \frac{dI_{ds}}{dV_{gs}} = \frac{\mu C_{OX}}{n}\left(\frac{W}{L}\right)V_{eff}$$

$$gm = \sqrt{\frac{2\mu C_{OX}}{n}\left(\frac{W}{L}\right)I_{ds}}$$

$$gm = \frac{Ids}{\left(\frac{V_{eff}}{2}\right)}, \quad \frac{gm}{Ids} = \frac{1}{\left(\frac{V_{eff}}{2}\right)}$$

$$V_{eff} = \sqrt{\frac{2n}{\mu} \cdot \frac{1}{C_{ox}} \cdot \frac{L}{W} \cdot I_{ds}}$$

Scaling W/L ratio

$$V_{eff} \propto \sqrt{L\frac{Ids}{W}} = \sqrt{L \cdot J_{ds}}$$

V_{eff} is proportional to square root of drain current density.

Non-ideal effects to square low region

At larger V_{eff} and lower V_{eff}, two non-ideal effects are not negligible .

Low V_{eff} Sub-threshold region

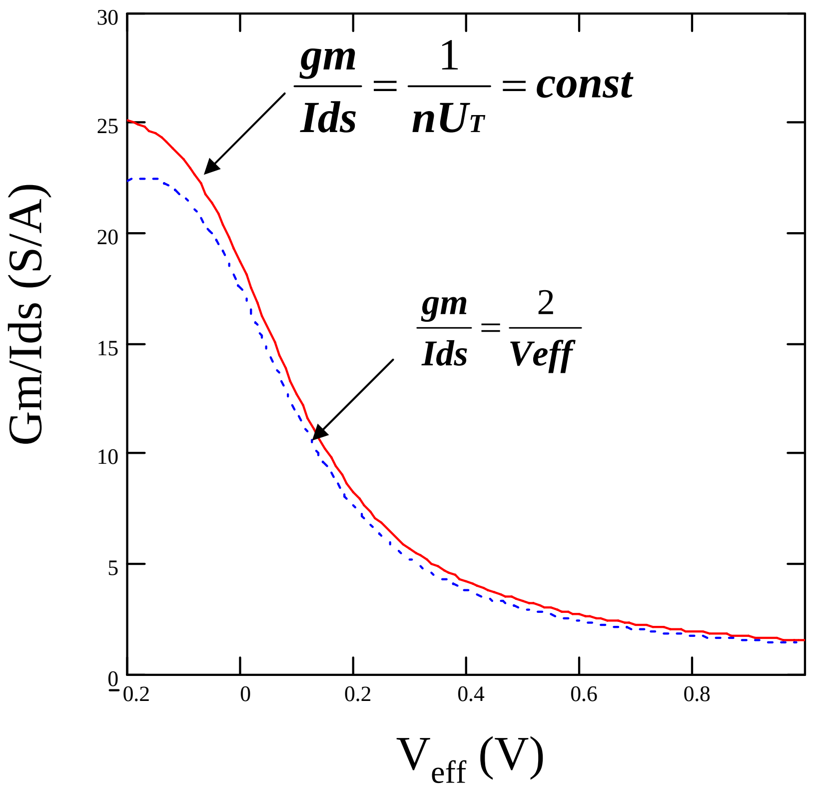
(Weak inversion)

$$I_{ds} = I_{so} \exp\left(\frac{V_{gs}}{nU_T}\right)$$

$$gm = \frac{I_{ds}}{nU_T} \qquad \frac{gm}{I_{ds}} = \frac{1}{nU_T}$$

High V_{eff} Mobility degradation

$$\mu \approx \frac{\mu_0}{1+\theta V_{eff}}, \quad \theta \approx \theta_0 + \frac{\mu_0}{v_c L}$$



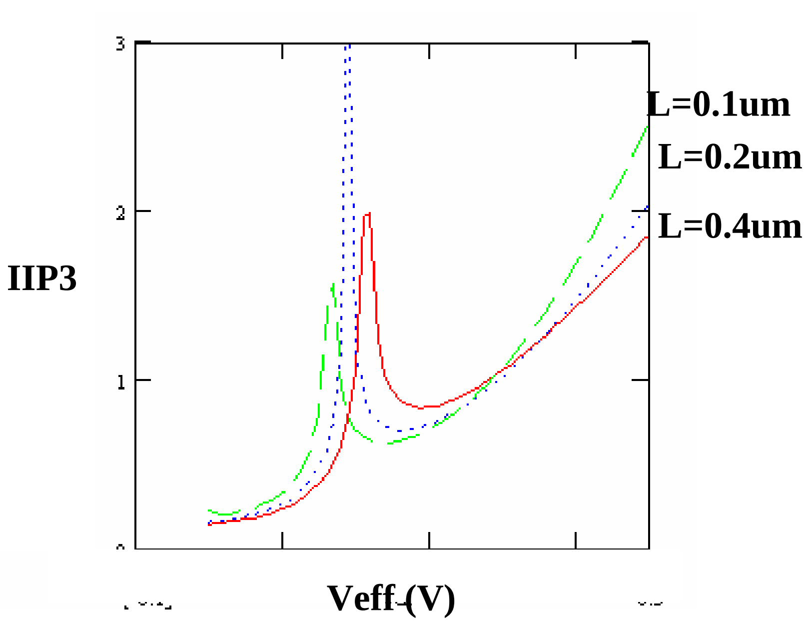
This effect becomes larger at large V_{eff} and short channel length.

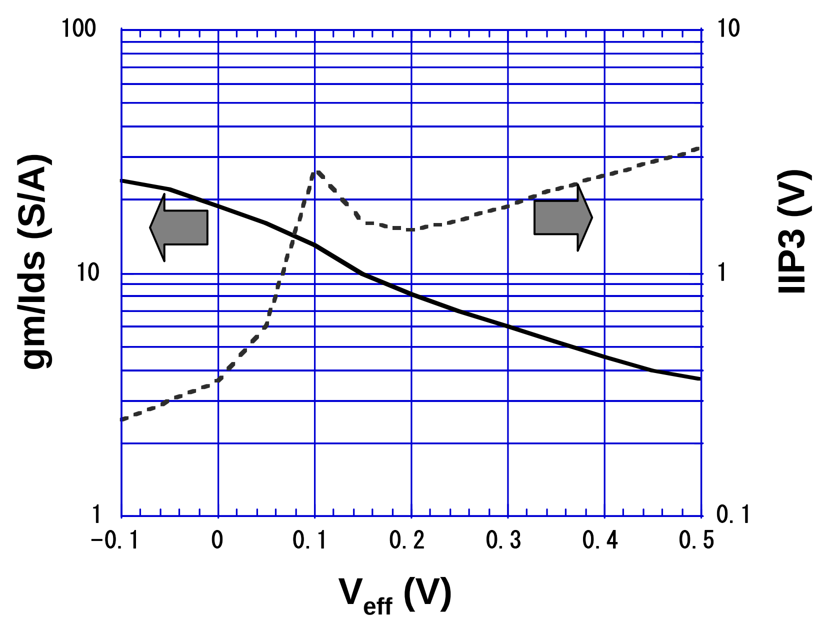
Distortion

Lower V_{eff} gives higher gm, bur results in higher distortion.
To obtain lower distortion (higher IIP3), we must increase V_{eff}.

Higher gm and lower distortion means higher Ids.

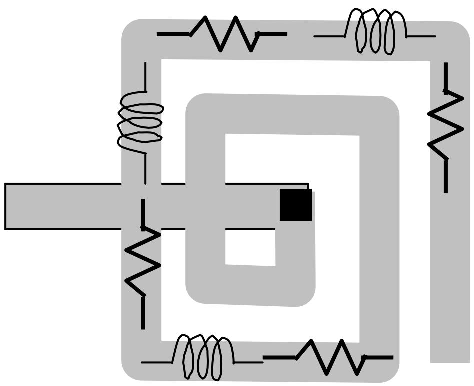
$$Ids = a_1 V_{eff} + a_2 V_{eff}^{\ 2} + a_3 V_{eff}^{\ 3} + \cdots \qquad a_3 \equiv \frac{1}{6}\frac{d^3 I_{ds}}{dV_{eff}^{\ 3}} \qquad I_{IP3} = \sqrt{\frac{4}{3}\left|\frac{a_1}{a_3}\right|}$$

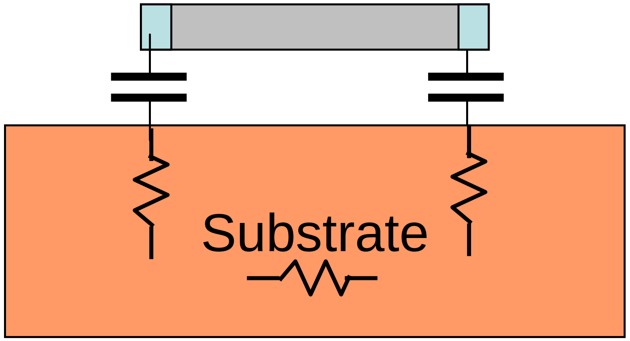


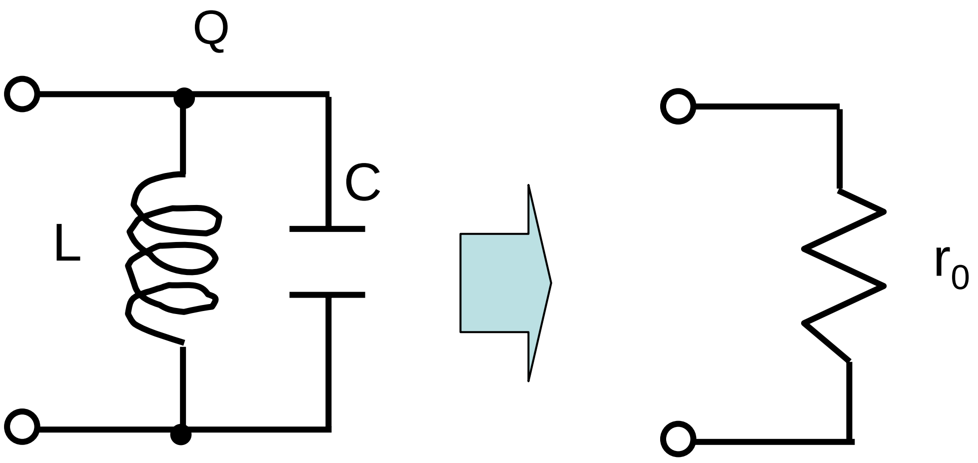


LC resonator

LC resonator can be regarded as resistance at the resonance frequency.







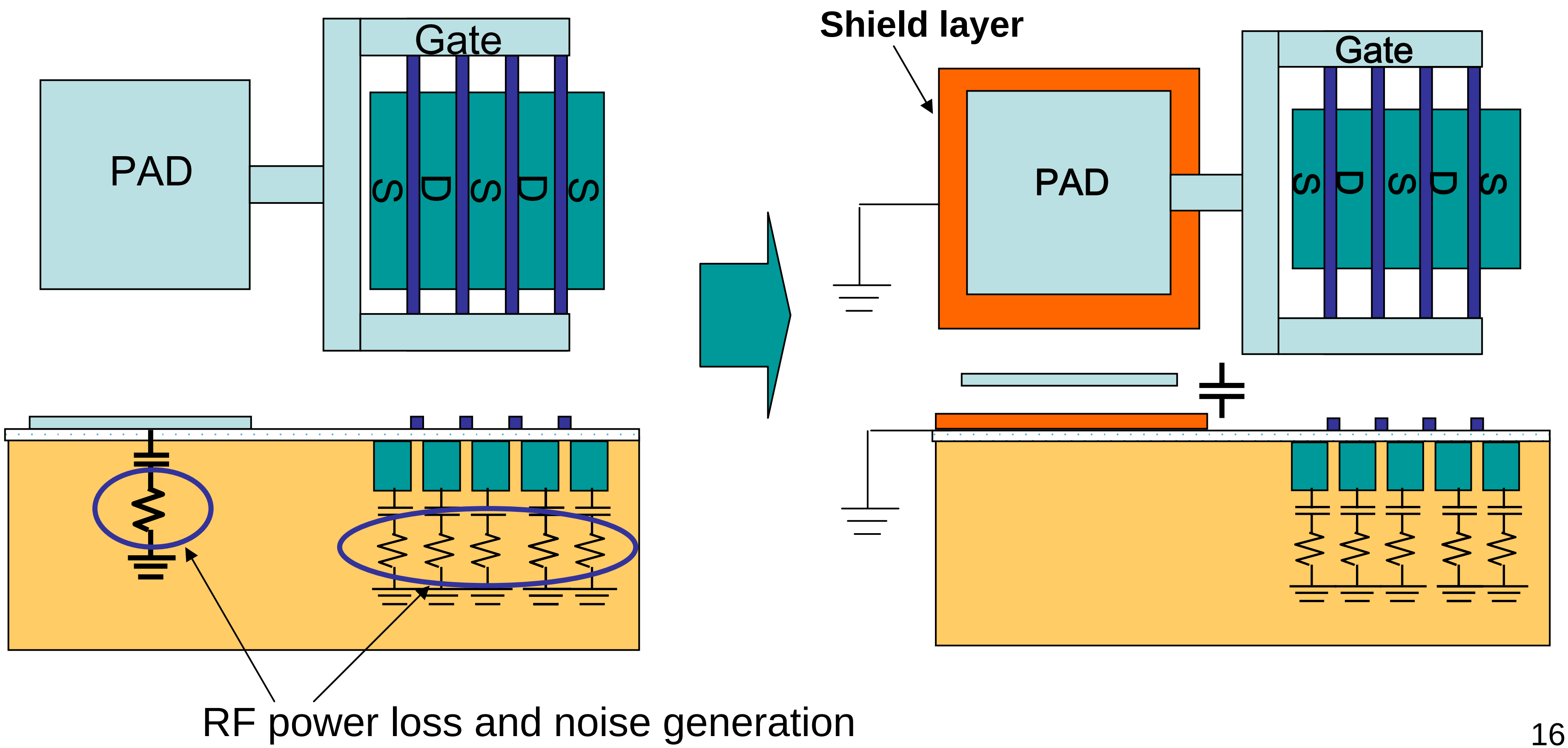
$$\omega_0 = \frac{1}{\sqrt{LC}} \qquad r_o = Q\omega_0 L = \frac{Q}{\omega_0 C}$$

Substrate effect

Substrate should be treated as resistive network.

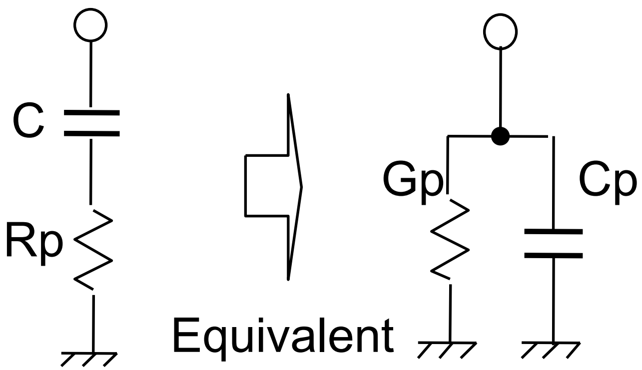
This substrate resistance causes RF power loss and noise generation.

Shielding can reduce this effect.



Power loss in substrate

Very low resistance or high resistance realizes low power loss.



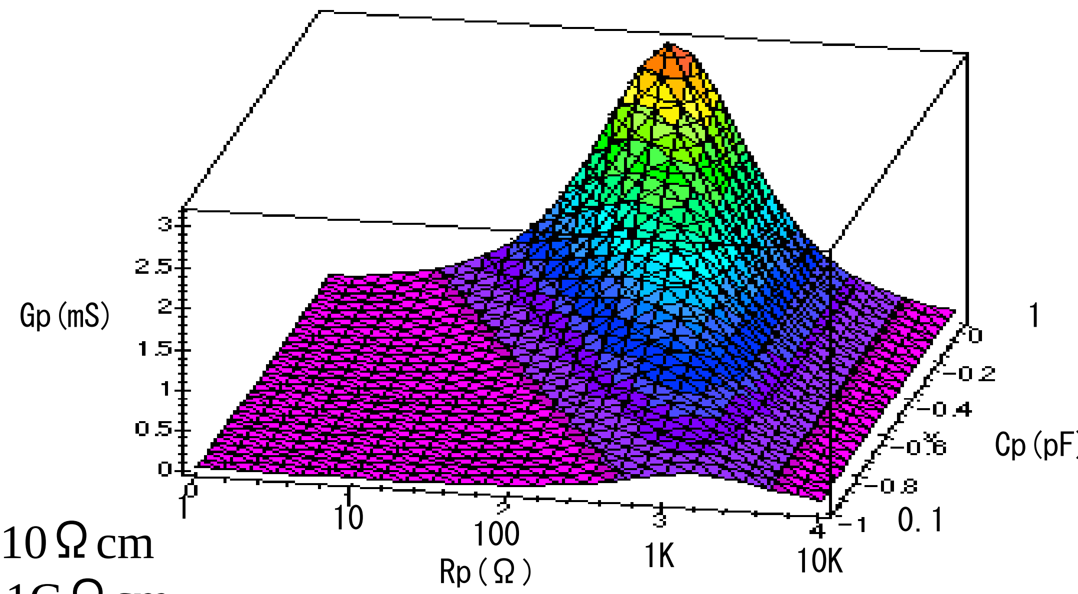
Higher C and moderate R_{sub} results in higher power loss.

$$G_p = \frac{1}{R_p} \cdot \frac{\left(\frac{\omega}{\varpi_p}\right)^2}{1 + \left(\frac{\omega}{\varpi_p}\right)^2}$$

$$C_p = C \frac{1}{1 + \left(\frac{\omega}{\varpi_p}\right)^2}$$

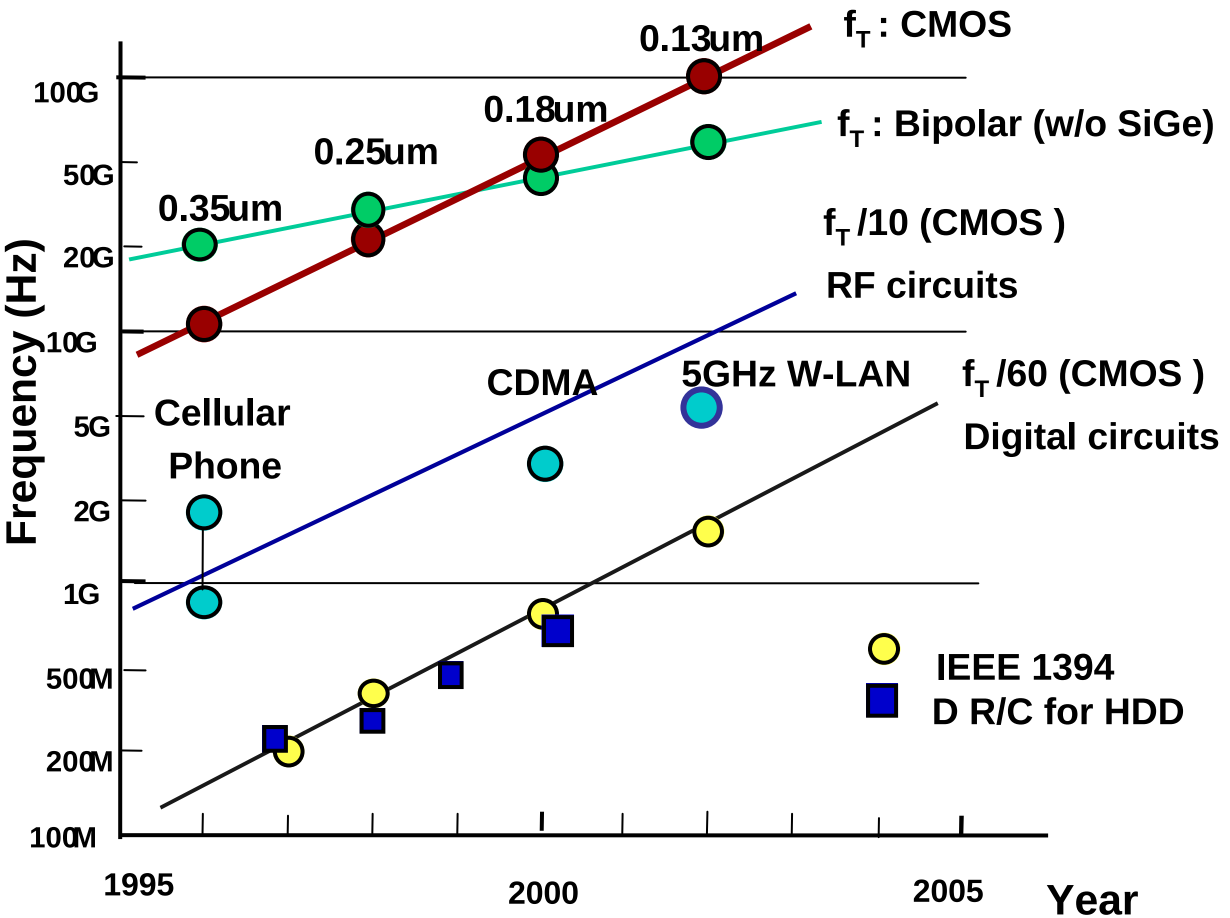
$$\varpi_p = \frac{1}{R_p C}$$

MOS: 10Ωcm
GaAs: 1GΩcm



GHz operation by CMOS

The cutoff frequency of MOS becomes higher than that of Bipolar.
Over several GHz operations have attained in CMOS technology



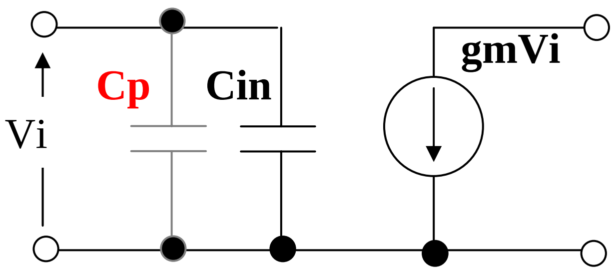
$$f_T \equiv \frac{gm}{2\pi C_{in}}$$

$$f_{Tpeak} \approx \frac{v_{sat}}{2\pi L_{eff}}$$

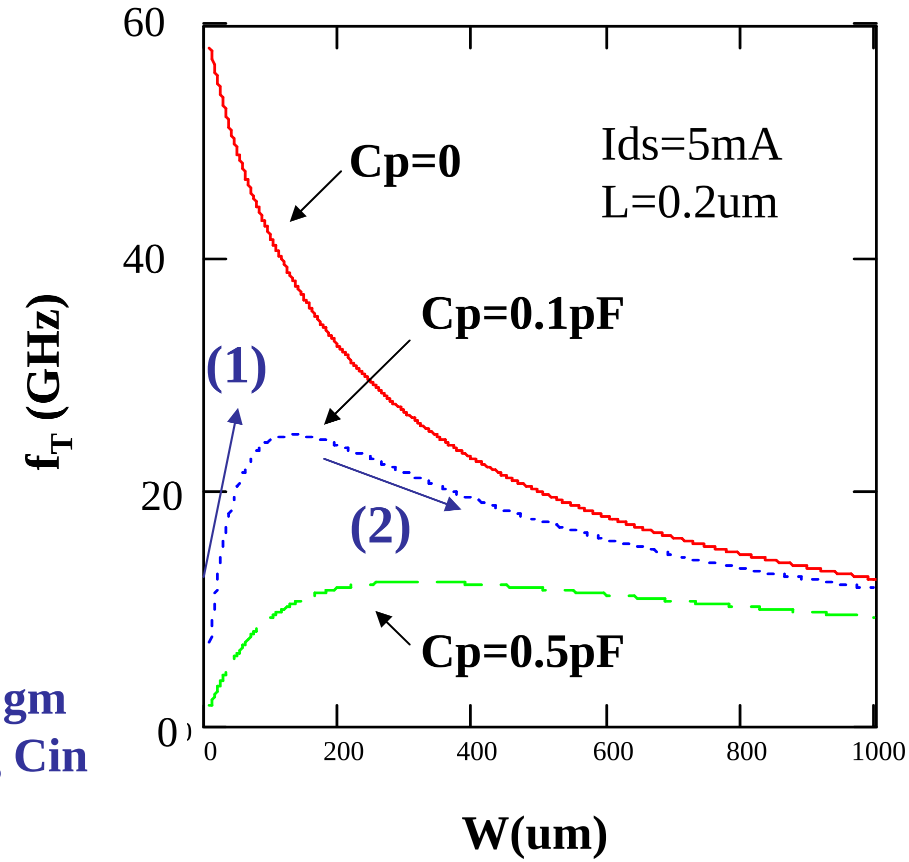
Effect of parasitic capacitance to f_T

f_T of actual circuit is reduced by a parasitic capacitance.
There is an optimum gate width to obtain highest f_T.

$$f_T \equiv \frac{gm}{2\pi(C_{gs} + C_{gd} + C_p)}$$



$C_{in}=C_{gs}+C_{gd}$



Region(1); Increased by increasing gm
Region(2); Decreased by increasing Cin

f_T: MOS vs. Bipolar

Even if f_T of MOS is the same as that of Bipolar,
f_T of MOS is easily lowered by a parasitic capacitance.
Because, gm of MOS is ½ to ¼ of that of Bipolar at the same current.

Small parasitic capacitance is a key for RF CMOS design.

MOS

$$gm \equiv \frac{Ids}{\left(\frac{V_{eff}}{2}\right)}$$

$$\boldsymbol{f_T \equiv \frac{gm}{2\pi Cin}}$$

Bipolar

$$gm \equiv \frac{Ic}{U_T}$$

$$\boldsymbol{U_T} \equiv \frac{\boldsymbol{kT}}{\boldsymbol{q}} \approx 26\boldsymbol{mV}$$

$$\boldsymbol{V_{eff}}_{\min} = 2\boldsymbol{nU_T}$$ n: 1.4

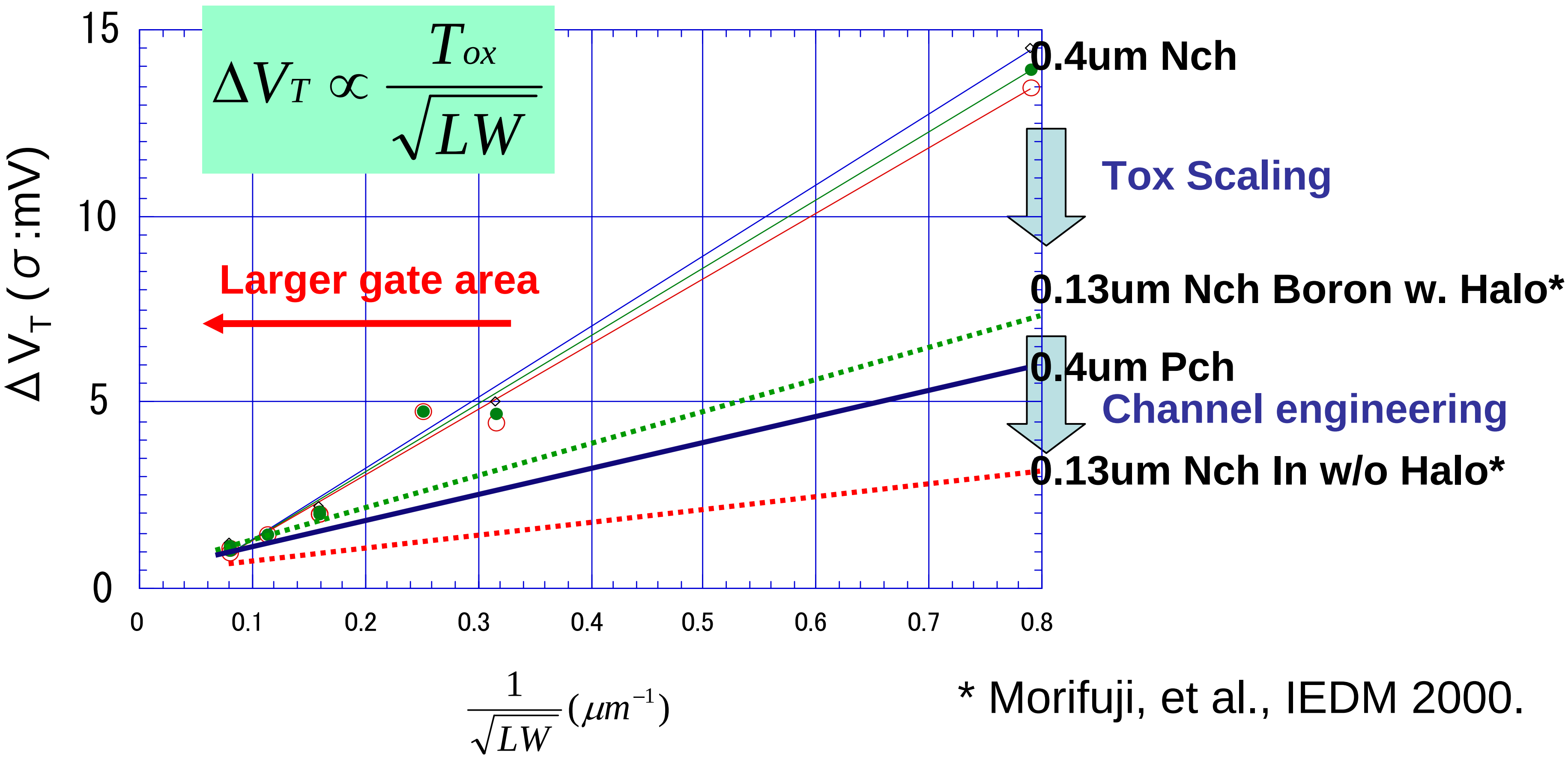
Veff/2: 50-100mV
(actual ckt.)

$$gm_{CMOS} < \frac{1}{2}, \frac{1}{4} gm_{Bip}$$ **（Same operating current）**

$$Cin_{CMOS} < \frac{1}{2}, \frac{1}{4} Cin_{Bip}$$ **（Same f_T）**

V_T mismatch

V_T mismatch degrades accuracy; ADC, OP amp, and Mixer.
Larger gate area is needed for small V_T mismatch.
Scaling and proper channel structure improves mismatch.



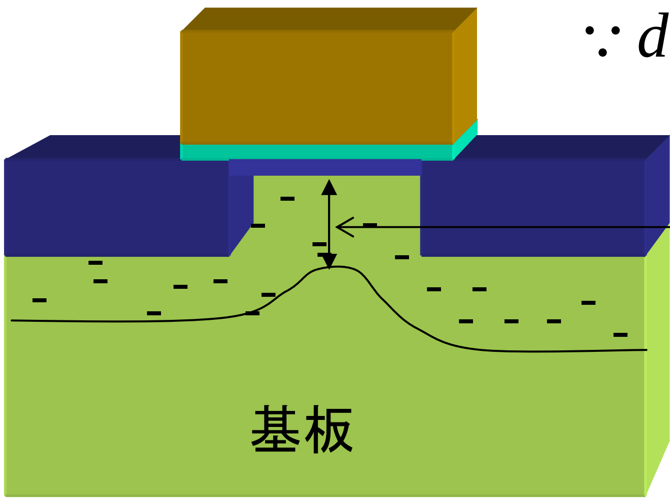
* Morifuji, et al., IEDM 2000.

V_T mismatch: Fluctuation of doping

Courtesy of Prof. Taniguchi, Osaka Univ.

$$\Delta V_T = \frac{\Delta Q_{depl}}{C_{ox}} = A t_{ox} \frac{\sqrt{LWd_{depl} N_A}}{LW} = A' t_{ox} \frac{\sqrt[4]{N_A}}{\sqrt{LW}} \approx A_{VT} \frac{t_{ox}}{\sqrt{LW}}$$

$$\because d_{depl} \propto \frac{1}{\sqrt{N_A}}$$



d_{depl}

$$A_{VT} = 1V$$

$$L = W = 0.25\mu m, \quad t_{ox} = 5nm$$

$$\Delta V_T = 20mV$$

T.Mizuno, J.Okamura and A.Toriumi, ”Experimental study o f threshold voltage fluctuation due to statistical variation of channel dopant number in MOSFETs,” IEEE Trans. On Electron Devices, ED-41, 2216 (1994)

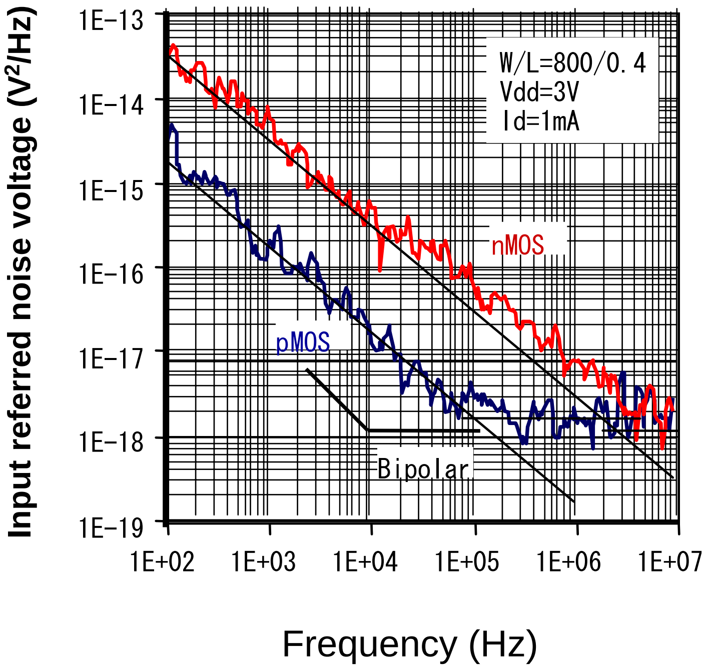
1/f noise

1/f noise of MOS is larger than that of bipolar.

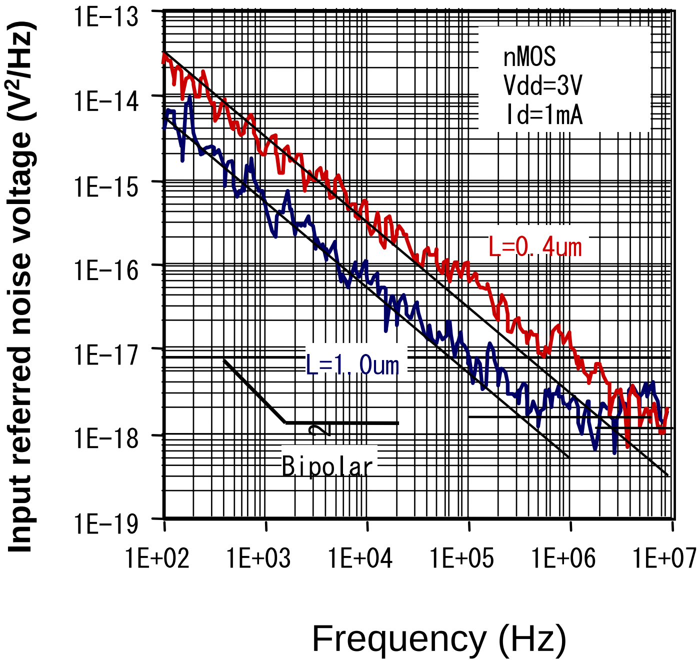
For the lower 1/f noise, the larger gate area is needed.

$$V_{nf}^2 = \frac{S_{vf}}{LW}\frac{\Delta f}{f}, \qquad S_{vf} \propto T_{ox}^2$$

Nch/Pch 0.4um

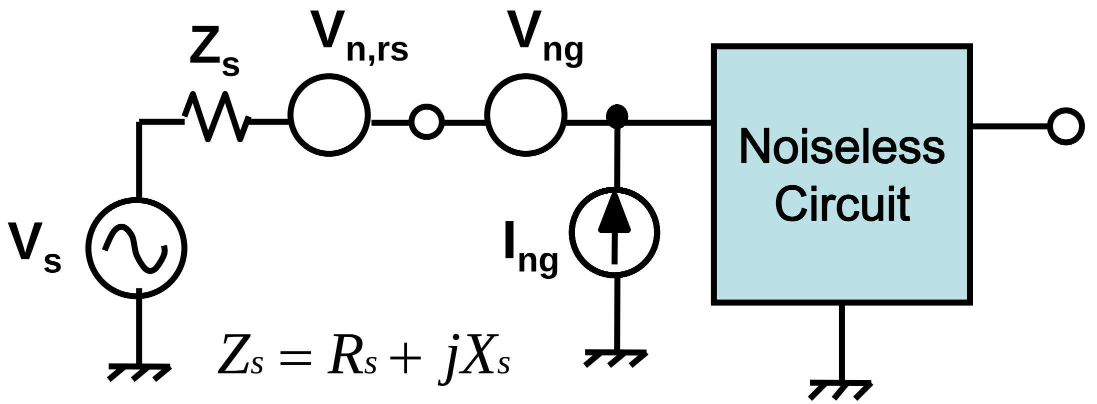


Nch 0.4um/1.0um



Noise figure: General

The lower R_{nv} and G_{ni} realizes the better for a lower noise figure.



$$Z_s = R_s + jX_s$$

$$\overline{V_{ng}^{\ 2}} = 4kTR_{nv}, \quad \overline{I_{ng}^{\ 2}} = 4kTG_{ni}$$

$$F = \frac{\overline{V_{n,rs}^2} + \overline{\left(V_{ng} + Z_s I_{ng}\right)^2}}{\overline{V_{n,rs}^2}} = 1 + \frac{R_{nv}}{R_s} + \frac{\left|Z_s\right|^2 G_{ni}}{R_s} \approx 1 + \frac{R_{nv}}{R_s} + R_s G_{ni}$$

$$R_{sopt} = \frac{\overline{V_{ng}}}{\overline{I_{ng}}} = \sqrt{\frac{R_{nv}}{G_{ni}}} \qquad F_{\min} \approx 1 + 2\sqrt{R_{nv} G_{ni}}$$

Noise figure: MOS transistor

$$F \approx 1 + \frac{R_{nv}}{R_s} + R_s G_{ni}$$

$$R_{nv} = R_g + R_{gs} \qquad R_g = R_{sr} \frac{W_{tot}}{L} \frac{1}{3N^2} \qquad R_{gs} \approx \frac{1}{5gm} \qquad G_{ni} \approx \frac{gm}{5} \left(\frac{\omega_0}{\omega_T} \right)^2$$

$$F \approx 1 + \frac{1}{Rs5gm} + Rs \frac{gm}{5} \left(\frac{\omega_0}{\omega_T} \right)^2 \qquad R_{sopt} \approx \frac{1}{gm} \left(\frac{\omega_T}{\omega_0} \right) = \frac{1}{C_{gs}\omega_0}$$

$$F_{\min} \approx 1 + 2\frac{\omega_0}{\omega_T}$$

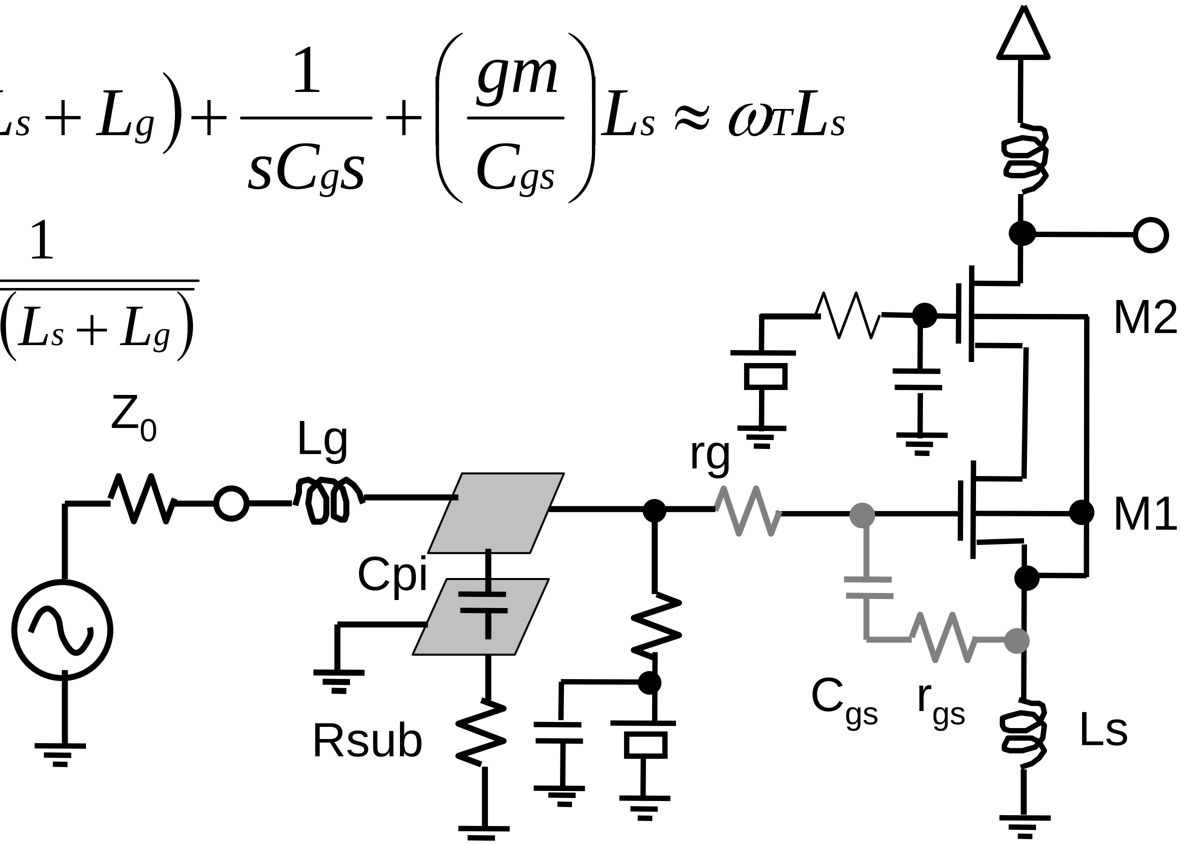
Low noise amplifier design

Narrowband LNA uses inductor degeneration for impedance matching.

Impedance matching

$$Z_{in} \approx s\left(L_s + L_g\right) + \frac{1}{sC_{gs}} + \left(\frac{gm}{C_{gs}}\right)L_s \approx \omega_T L_s$$

$$\omega_0 = \frac{1}{\sqrt{C_{gs}\left(L_s + L_g\right)}}$$



Low NF design

$$F \approx 1 + \frac{r_{gs} + r_g}{Z_0} + 4\gamma g m Z_0 \left(\frac{\omega_0}{\omega_T} \right)^2 \approx 1 + \frac{r_{gs} + r_g}{Z_0}$$

$$r_{gs} \approx \frac{1}{5gm}$$

Low noise figure

1) Lower the gate resistance

Dived the gate or lower the gate sheet resistance

$$r_g = R_{sr} \frac{W_{tot}}{L} \frac{1}{3N^2}$$

$$r_g = R_{sr} \frac{W_{tot}}{L}$$

Rsr: Sheet resistance

N : The # of division

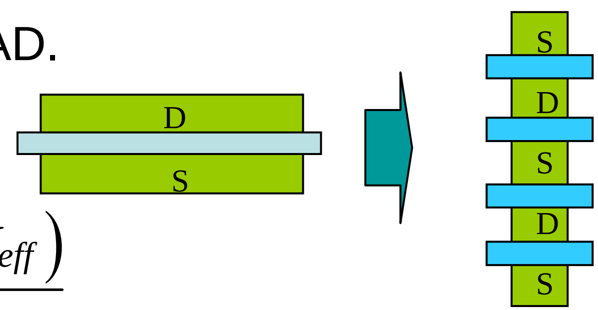
Divide the gate

2) Reduce substrate loss

Reduce parasitic capacitance

Use shield technique to the input bonding PAD.

Use high resistive substrate, if possible.



3) Increase drain current

4) Increase Z_0, if possible.

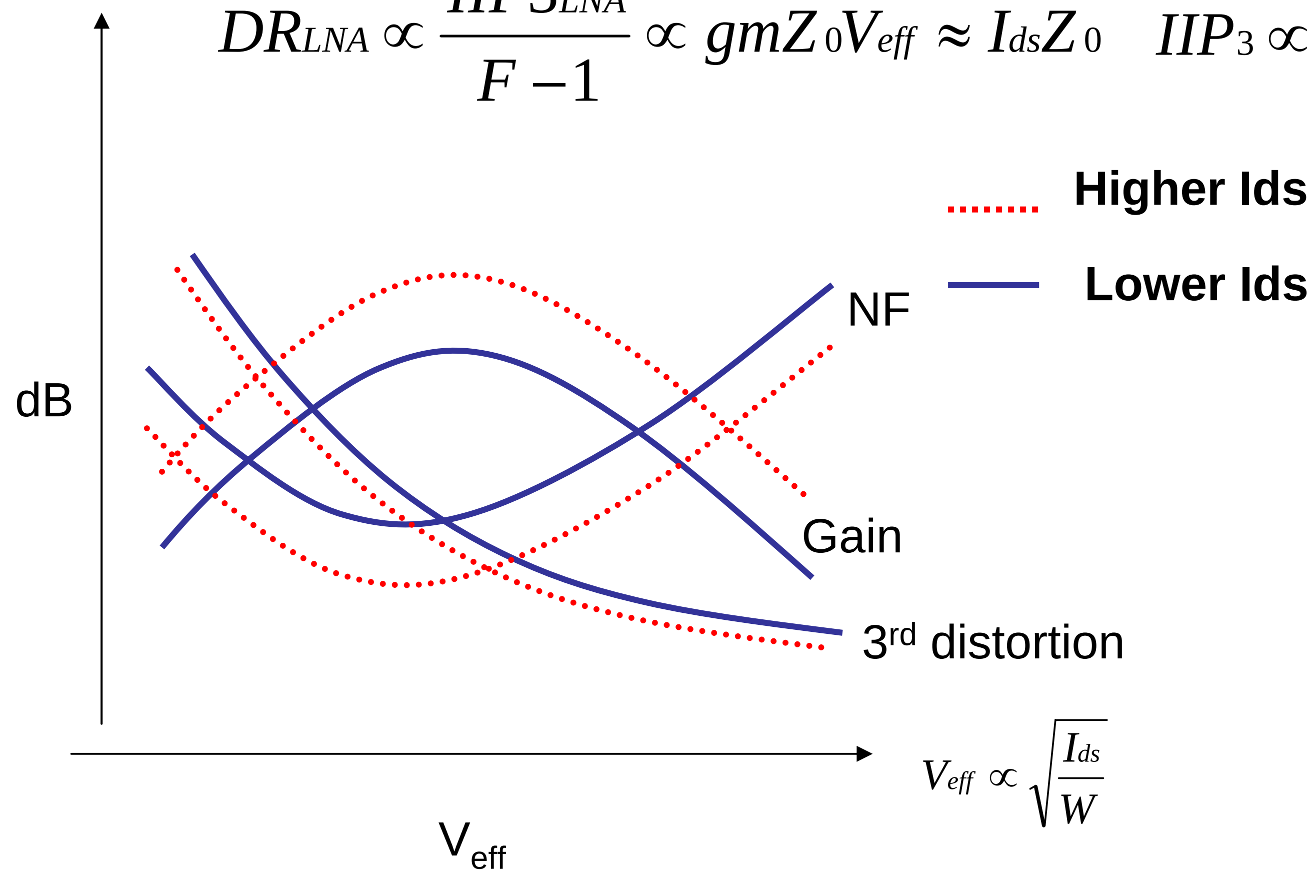
$$r_{gs} \approx \frac{1}{5gm} \approx \frac{(V_{eff})}{10 I_{ds}}$$

I_{ds} and V_{eff} optimization

Adjust the I_{ds} and V_{eff} for optimization of gain, noise and distortion.

Dynamic range of LNA is proportional to Ids.

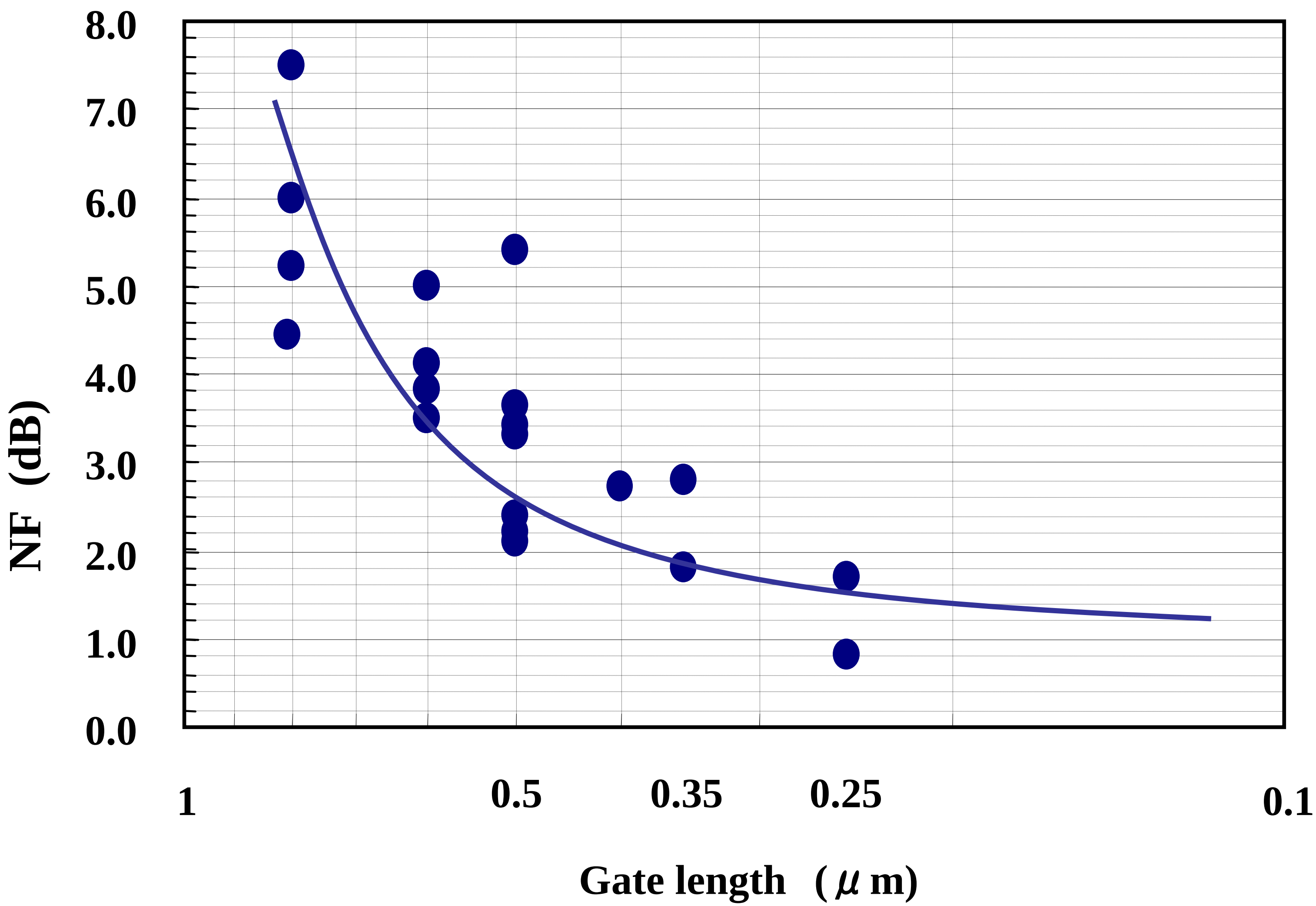
$$DR_{LNA} \propto \frac{IIP3_{LNA}}{F-1} \propto gmZ_0V_{eff} \approx I_{ds}Z_0 \qquad IIP_3 \propto V_{eff}$$



$$V_{eff} \propto \sqrt{\frac{I_{ds}}{W}}$$

NF progress in MOS LNA

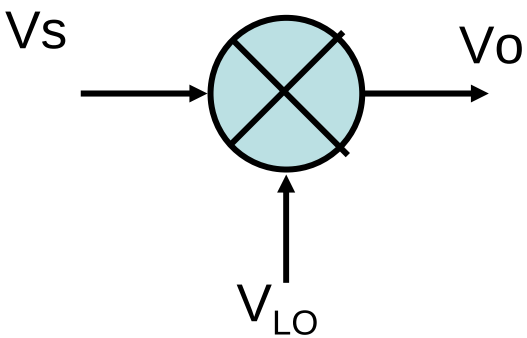
NF of MOS LNA is reaching 1dB.



Mixer

Mixer converts frequency, but image signal is converted to the same frequency.

$$V_s = A_s \cos(\omega_s t)$$



$$V_o = A_s \frac{2}{\pi} \cos((\omega_s \pm \omega_{LO})t)$$

If V_{LO}>>4V_{eff} (Full swing)

$$V_{LO} = A_{LO} \cos(\omega_{LO} t)$$

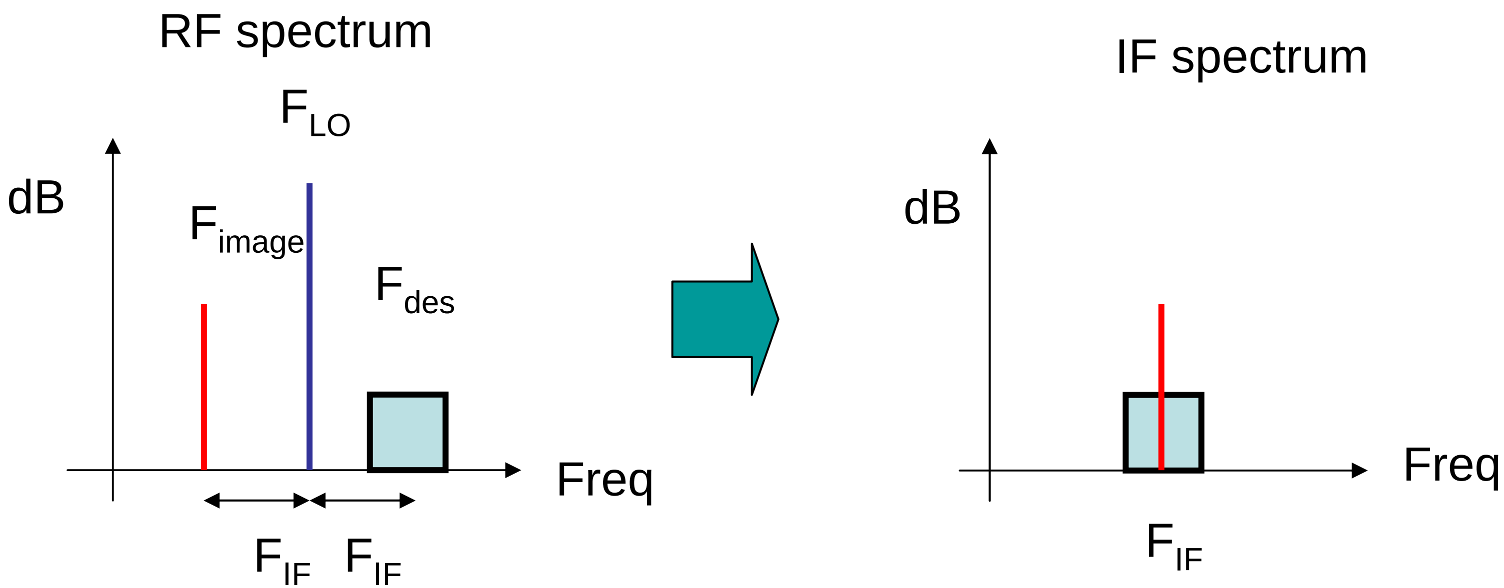
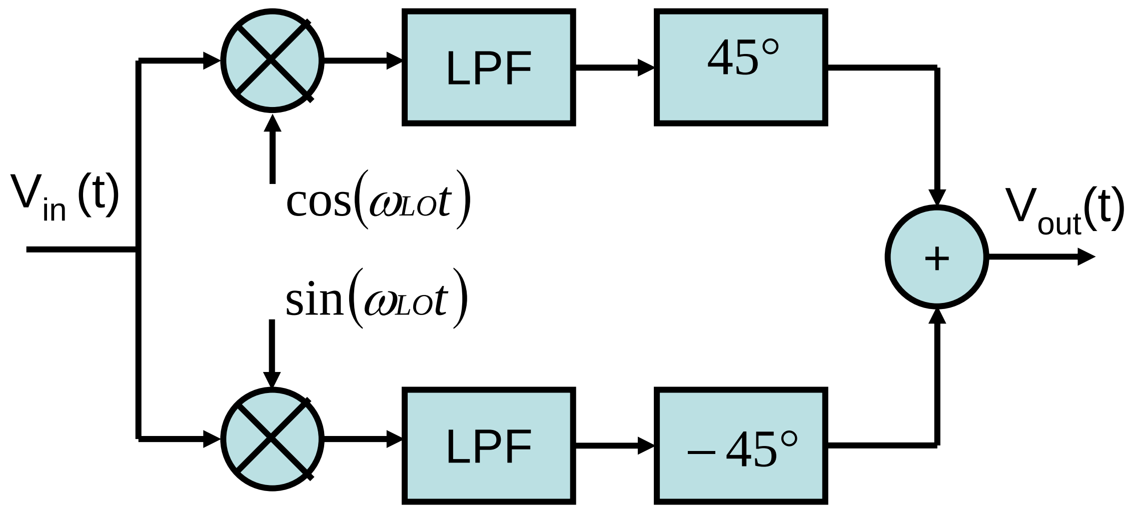


Image-reject mixers

The quadrature mixing realizes image-suppression.
Gain and phase matching is needed.



$$V_{in}(t) = A_{des}\cos(\omega_{des} t) + A_{im}\cos(\omega_{im} t)$$

$$V_{out}(t) = A_{des}A_c\cos(\omega_{IF} t) + A_{im}A_c I_R\cos(\omega_{IF} t)$$

A_c: Conversion gain, I_R: Image rejection

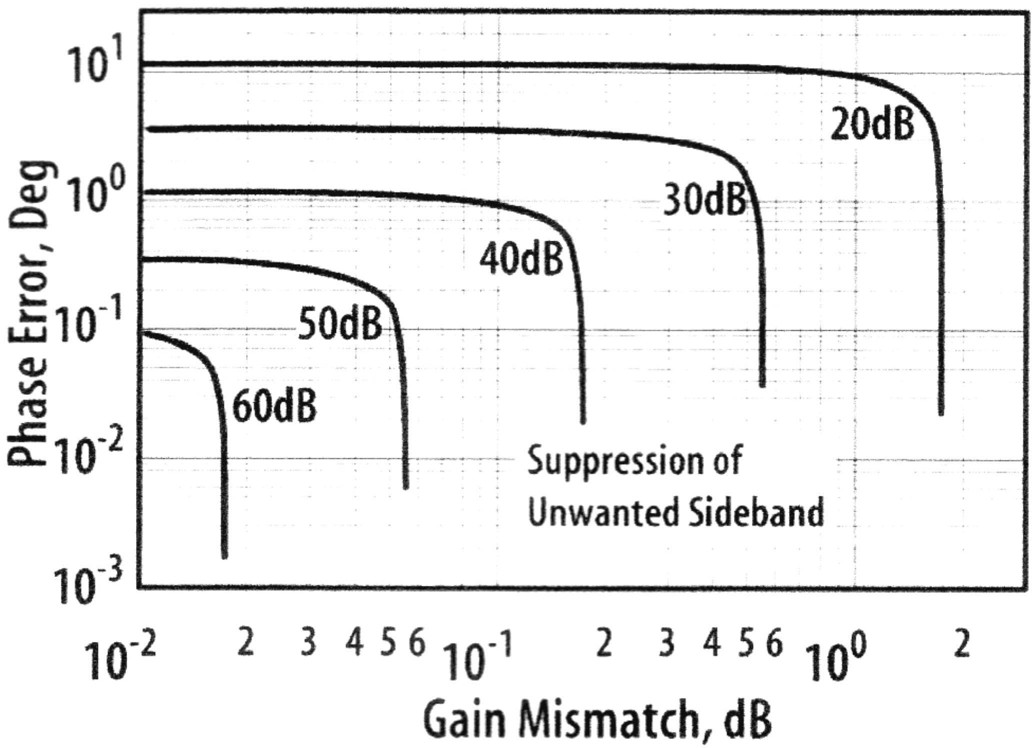
I_R=0 if I/Q phase difference is 90° and Channel conversion gains are equal.

Gain mismatch and phase error

$$\frac{P_{spur}}{P_{desired}} = \frac{1+\gamma^2 - 2\gamma\cos\phi}{1+\gamma^2 + 2\gamma\cos\phi}$$

γ : Gain ratio

ϕ :Phase error



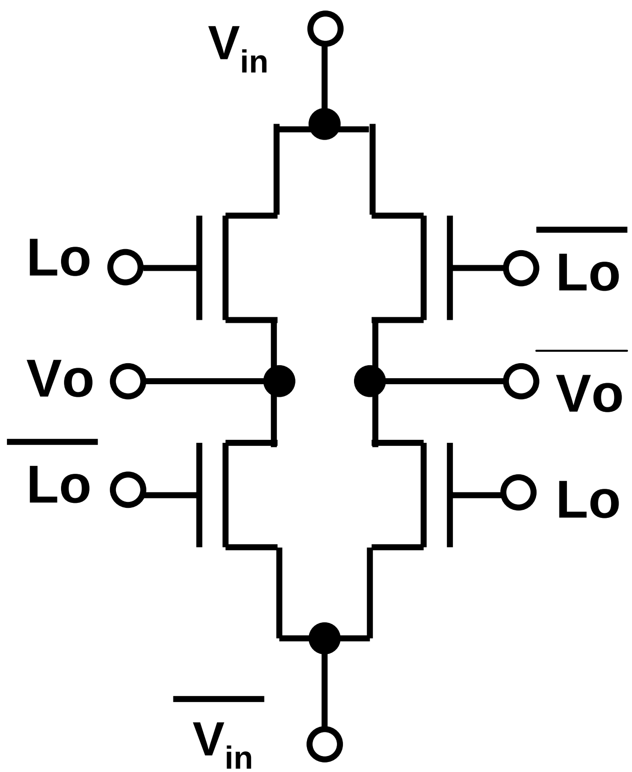
A. Rofougaran, et al., IEEE J.S.C. Vol.33, No.4, April 1998. PP. 515-534.

Passive FET mixer

MOS can realize a passive mixer easily.

Ultimately low power, but take care of isolation.

Passive FET mixer

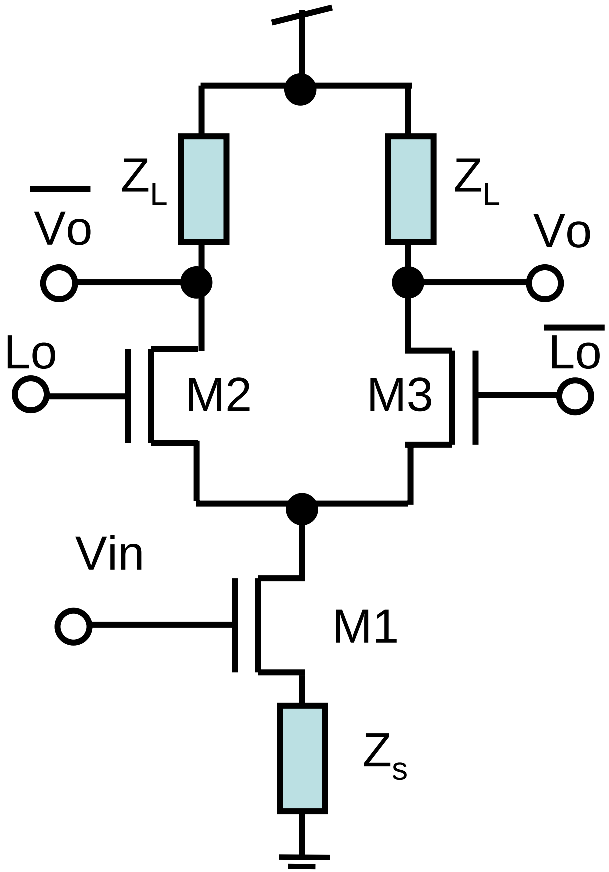


Low power
High linearity
No 1/F noise

No conversion gain
No isolation, Bi-directional

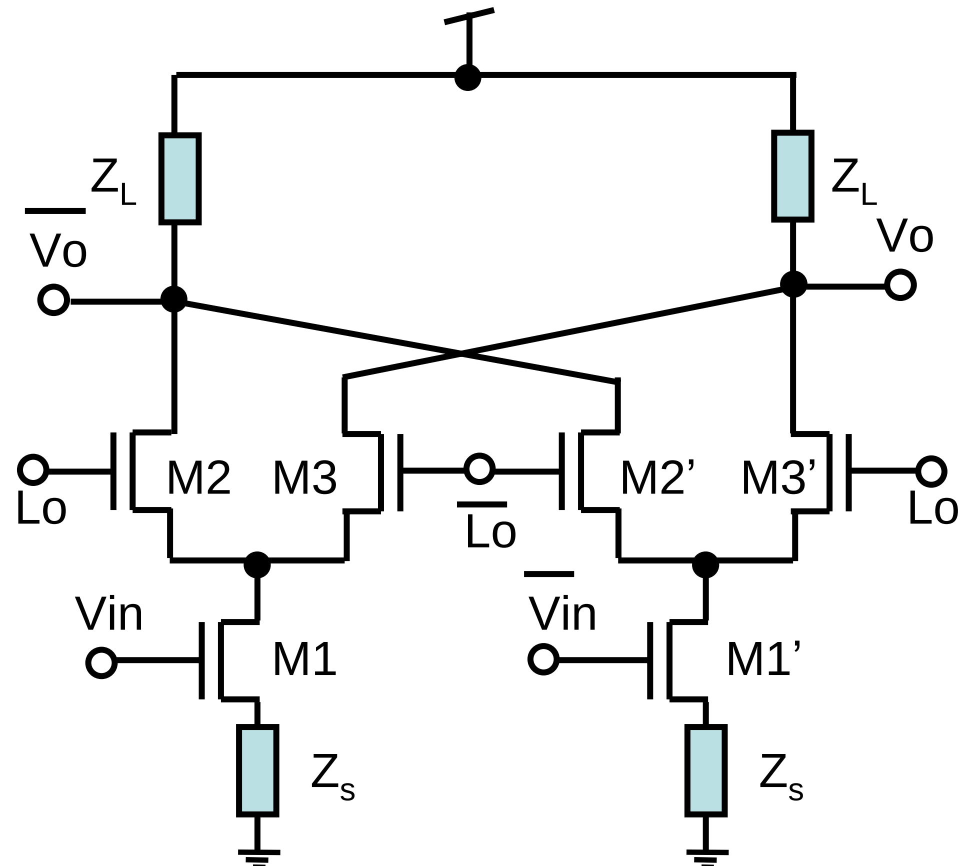
Active mixers

Single balanced mixer



Double balanced mixer

Very small direct feed through and even order distortion



Active mixer design

The larger Ids is needed for high dynamic range and shorter switching time for low 1/f noise.

Mixer gain $G_{mix} = \frac{2}{\pi} gm_1 Z_L, or = \frac{2}{\pi}\frac{Z_L}{Z_s}$ when Z_s is used

R_L: Resistive component in ZL

Thermal noise $v_{on}^{2} = 8kTR_L\left(1 + \frac{2\gamma IR_L}{\pi A_{LO}} + \gamma gm_1 R_L\right) \approx 8kTR_L^2 \gamma gm_1$

$$SSBv_{in}^2 = \frac{v_{on}^{2}}{\left(\frac{2}{\pi} gm_1 R_L\right)^2} \approx 2\pi^2 kT \frac{\gamma}{gm_1} \cong \pi^2 kT\gamma \frac{V_{eff}}{I_{ds}}$$

$$IIP3 \approx V_{eff}$$

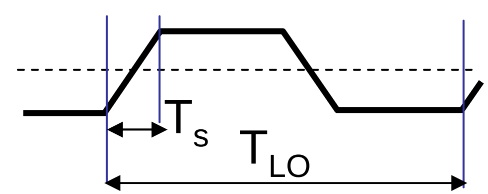
A larger dynamic range needs larger current

1/F noise

1) Switch transistor (M2, M3)

$$v_{n,o} = \frac{4Ts}{T_{LO}} v_{n,sw}$$

$$v_{n,sw}^2 \approx \frac{1}{WL} \propto \frac{1}{Cgs}$$



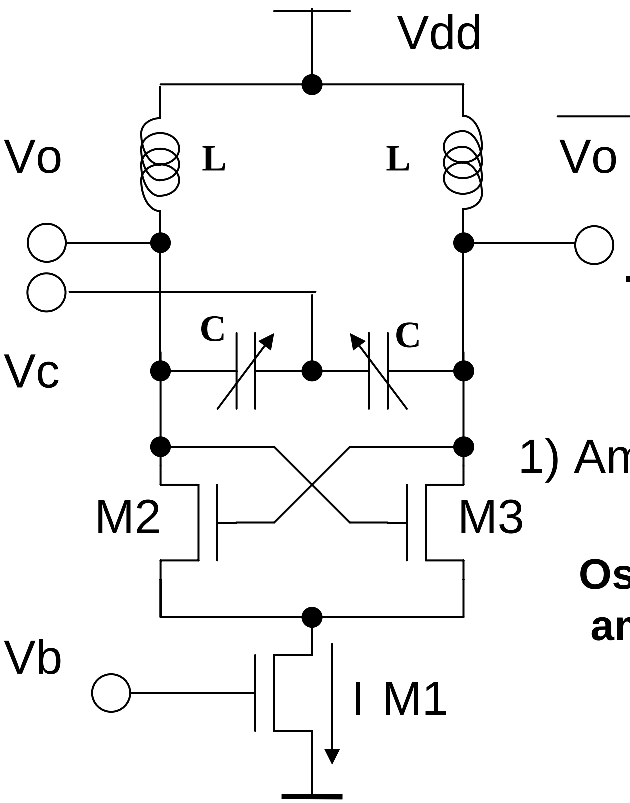
Phase modulation

Shorter switching time or larger T_s/T_{Lo} ratio

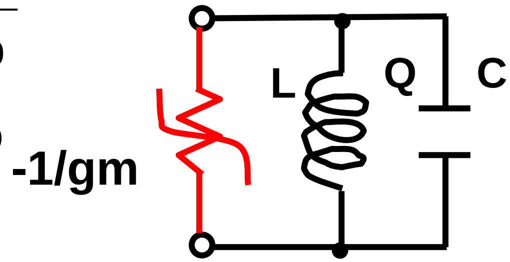
2) Load transistors Directly produces

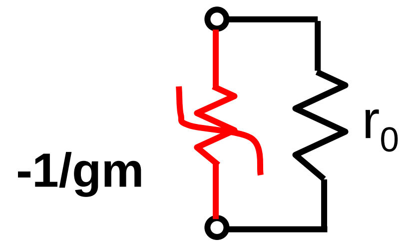
Oscillator

There is an optimum Ids for low phase noise.



(a)





$$r_o = Q\omega_0 L = \frac{Q}{\omega_0 C}$$

1) Amplitude condition

Oscillation amplitude $V_{osc} = \frac{4Ir_o}{\pi}$ **Headroom limit** 2Vdd

$$I_{opt} = \frac{\pi V_{dd}}{2r_o} = \frac{\pi V_{dd}\omega_o C}{Q}$$

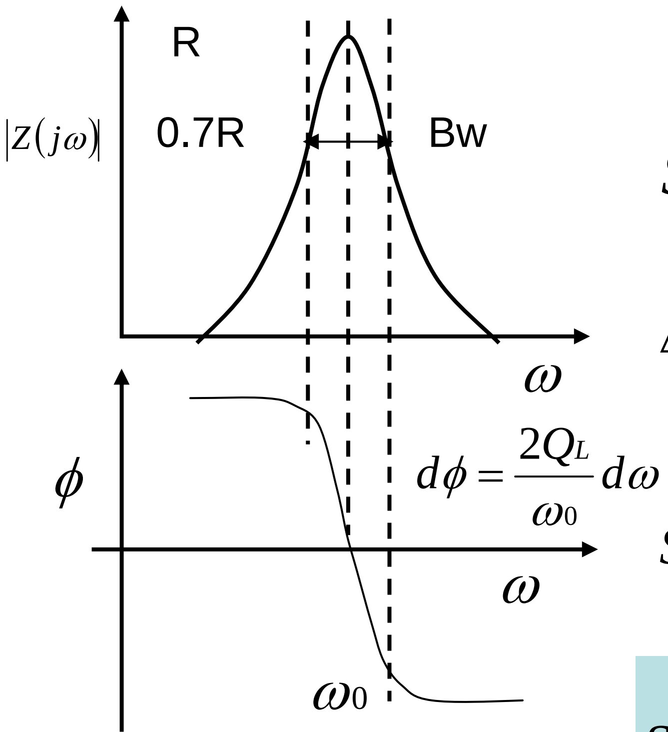
2) Oscillation condition

$$gm_{2,3} > \frac{2}{r_o}, \qquad I > \frac{\omega_o C V_{eff,2,3}}{Q}$$

Phase noise of oscillator

Phase-frequency relation and resonator characteristics determine phase noise.

$$\frac{1}{Bw} = \frac{2Q_L}{\omega_0}$$



$$v(t) = A\cos[\omega_0 t + \phi(t)]$$

$$\omega_m = \frac{d\phi}{dt} = j\omega\phi$$

$$S_\omega(\omega_m) = \omega_m^2 S_\phi(\omega_m)$$

$$\Delta\theta = \frac{\omega_m}{Bw} = \frac{2Q_L}{\omega_0}\omega_m$$

$$S_\omega(\omega_m) = \left(\frac{\omega_0}{2Q_L}\right)^2 S_{\Delta\theta}(\omega_m) \qquad \omega_m < Bw$$

ω_m : Offset angular frequency

$S_\omega(\omega_m)$:Noise spectrum density on offset angular frequency

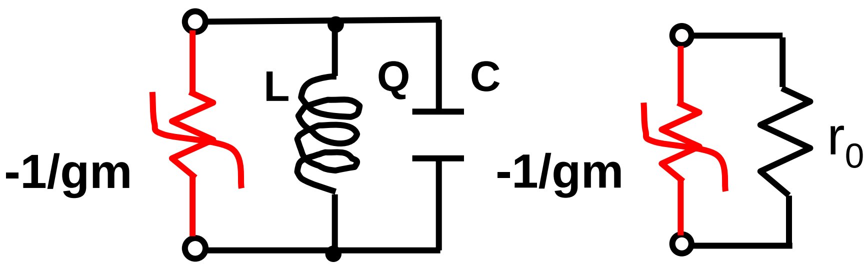
$S_\phi(\omega_m)$:Noise spectrum density on phase

$\Delta\theta$ Phase error between in and out

$S_{\Delta\theta}(\omega_m)$:Noise spectrum density on phase error

$$S_\phi(\omega_m) = \left(\frac{\omega_0}{2Q_L}\right)^2 \frac{1}{\omega_m^2} S_{\Delta\theta}(\omega_m) = \left(\frac{\omega_0}{2Q_L\omega_m}\right)^2 S_{\Delta\theta}(\omega_m)$$

Phase noise of oscillator



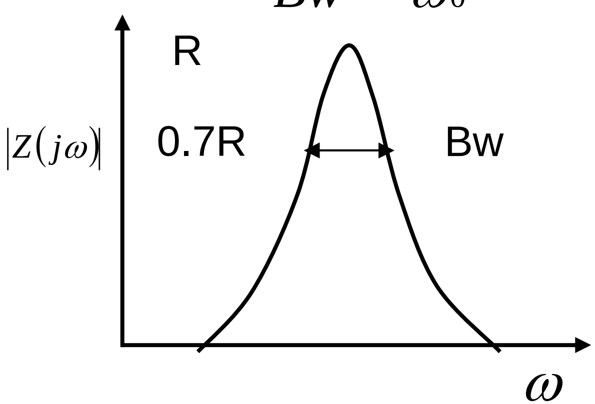
$$Z(\omega_0+\omega_m)\approx j\frac{\omega_0 L}{2\frac{\omega_m}{\omega_0}} \qquad \omega_m << \omega_0$$

(Filter action)

$$Q=\frac{r_0}{\omega_0 L}$$

$$\left|Z(\omega_0+\omega_m)\right|\approx\frac{r_0\omega_0}{2Q\omega_m}$$

$$\frac{1}{Bw}=\frac{2Q}{\omega_0}$$



$$\frac{\overline{v_n^2}}{\Delta f}=\frac{\overline{i_n^2}}{\Delta f}\cdot|Z|^2=4kTr_o\left(\frac{\omega_0}{2Q\omega_m}\right)^2$$

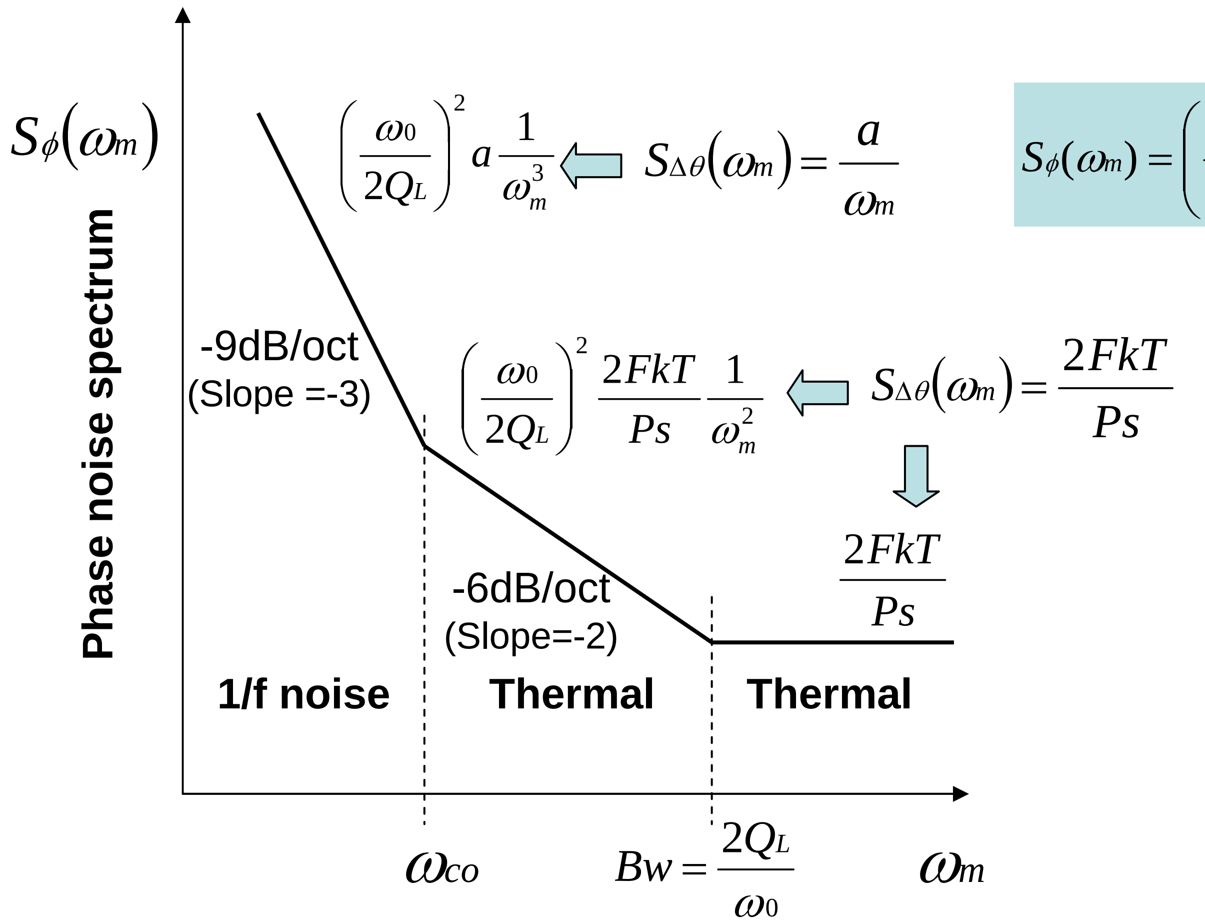
Noise spectrum density

$$L\{\omega_m\}=10\log\left[\frac{2kT}{P_{sig}}\cdot\left(\frac{\omega_0}{2Q\omega_m}\right)^2\right]$$

Phase noise

Frequency characteristics of Phase noise in oscillator

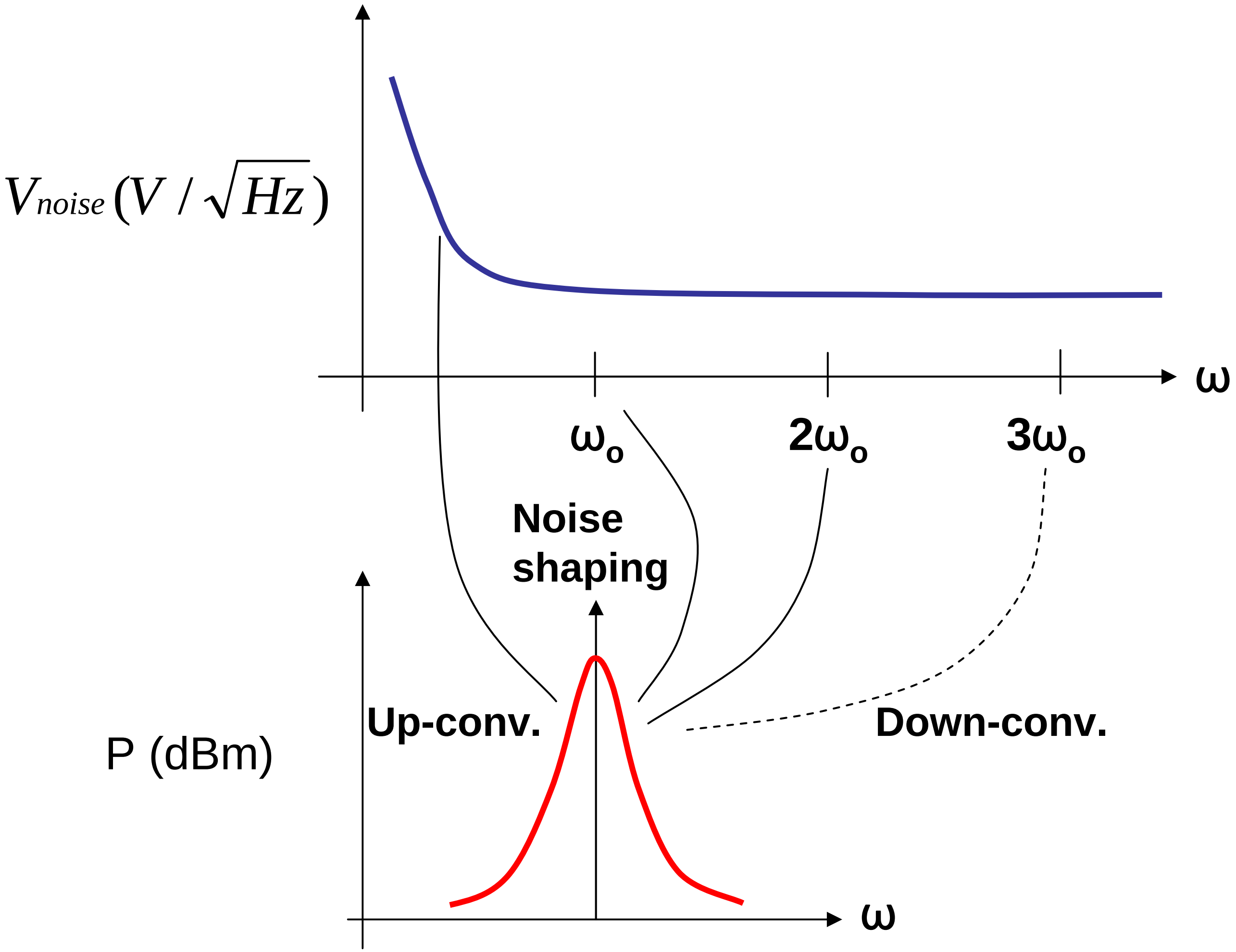
1/f noise and thermal noise is converted to $1/f^3$ and $1/f^2$, respectively.



$$S_\phi(\omega_m) = \left(\frac{1}{2Q_L}\frac{\omega_0}{\omega_m}\right)^2 S_{\Delta\theta}(\omega_m)$$

Up and down converted noise

Noises around N*fo are up and down converted to fo.



FoM and minimum phase noise

FoM is basically proportional to Q^2.

$$FoM = \left(\frac{f_0}{f_m}\right)^2 \frac{1}{L(f_m)V_{dd}I}$$

Fm: Offset frequency
L(fm): Phase noise at offset freq.

$$L(f_m) = \frac{1}{2}\cdot\frac{1}{Q^2}\cdot\left(\frac{f_o}{f_m}\right)^2\cdot\frac{FkT}{P_{RF}} = \frac{1}{2}\cdot\frac{1}{Q^2}\cdot\left(\frac{f_o}{f_m}\right)^2\cdot\frac{FkT}{\left(\frac{V_o^2}{2ro}\right)}$$

F: Noise factor

$$F = 2 + \frac{8\gamma r_o I}{\pi V_o} + \gamma\frac{8}{9}r_o\cdot g_{m1}$$

$$I_{opt} = \frac{\pi V_{dd}}{2r_o} = \frac{\pi V_{dd}\omega_o C}{Q} = \frac{\pi V_{dd}}{2Q\omega_o L_{ind}}$$

$$FoM = \frac{4}{\pi}\frac{Q^2}{kT}\frac{1}{2+4\gamma+\frac{32}{9}\gamma\pi\frac{V_{dd}}{V_{eff,1}}} \propto Q^2$$

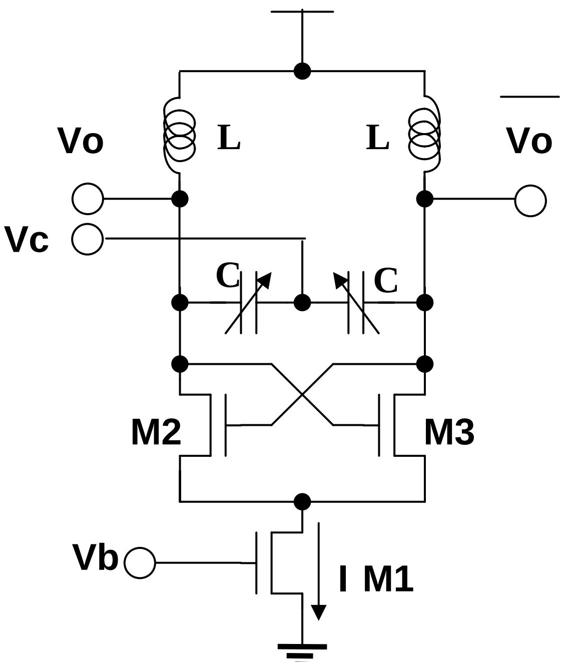
at I_{opt}

Oscillator design

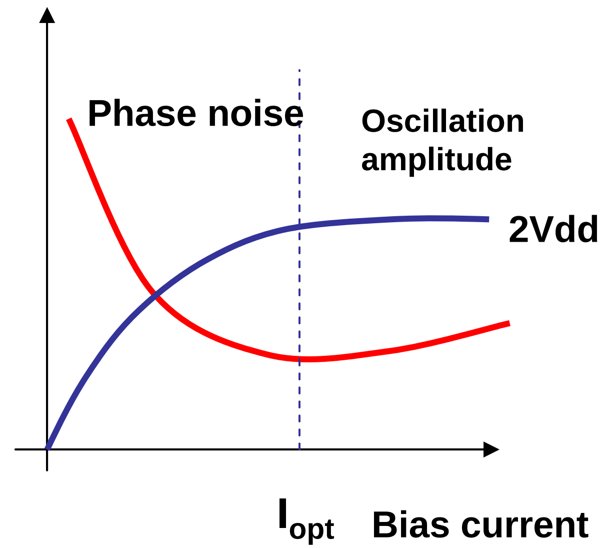
Careful optimization reduces the oscillator phase noise.

$$L_{\min}(f_m) = kT \cdot \frac{\gamma}{V_{dd}} \cdot \frac{\omega_o L_{ind}}{2Q} \cdot \left(\frac{1}{V_{dd}} + \frac{2}{V_{eff,1}}\right)\left(\frac{f_o}{f_m}\right)^2$$

$$L_{\min}(f_m) = kT \cdot \frac{\gamma}{2I_{opt}} \cdot \frac{1}{2Q^2} \cdot \left(\frac{1}{V_{dd}} + \frac{2}{V_{eff,1}}\right)\left(\frac{f_o}{f_m}\right)^2$$



$$I_{opt} = \frac{\pi V_{dd}}{2r_o} = \frac{\pi V_{dd}\omega_o C}{Q} = \frac{\pi V_{dd}}{2Q\omega_o L_{ind}}$$



Larger V_{dd}
Large V_{eff1}, but take care of V_o reduction
Large L_1, W_1 to reduce 1/f noise
Enough W/L for M2, M3
Higher Q
Larger QL_{ind} for Lower I_{opt}

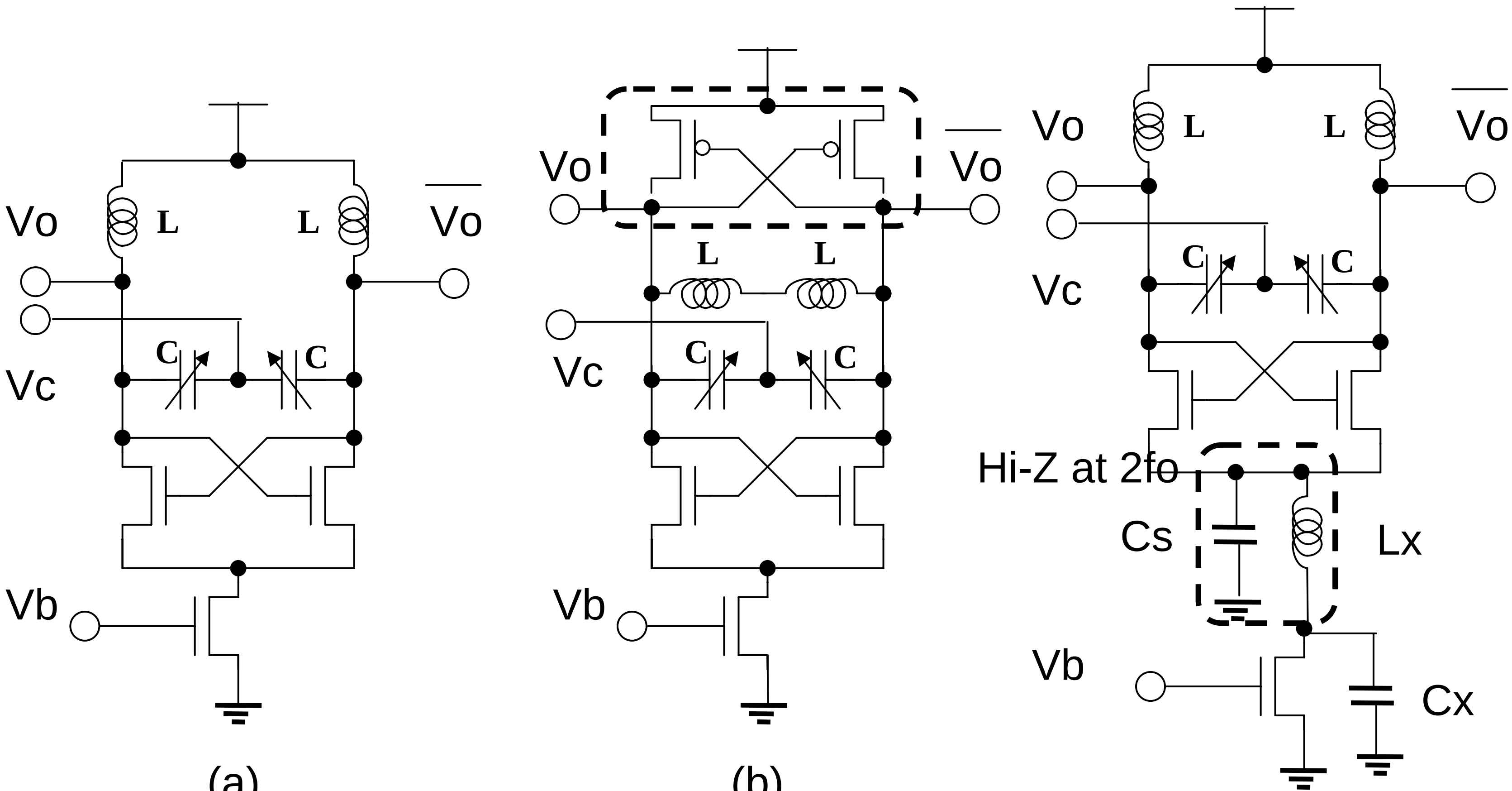
CMOS oscillator circuits

E. Hegazi, ISSCC 2001

Basic

Low power (gm is higher)

Low noise by filtering

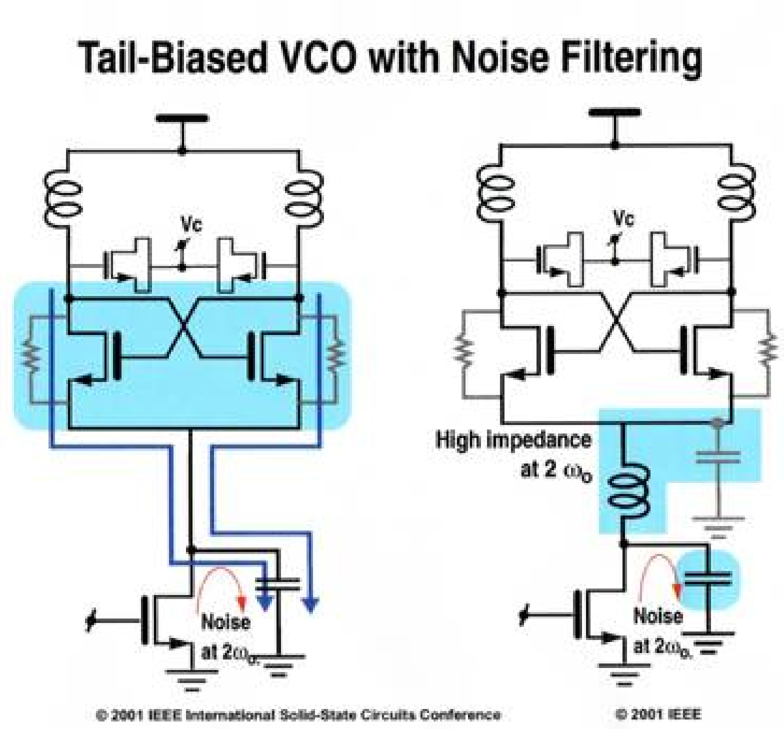


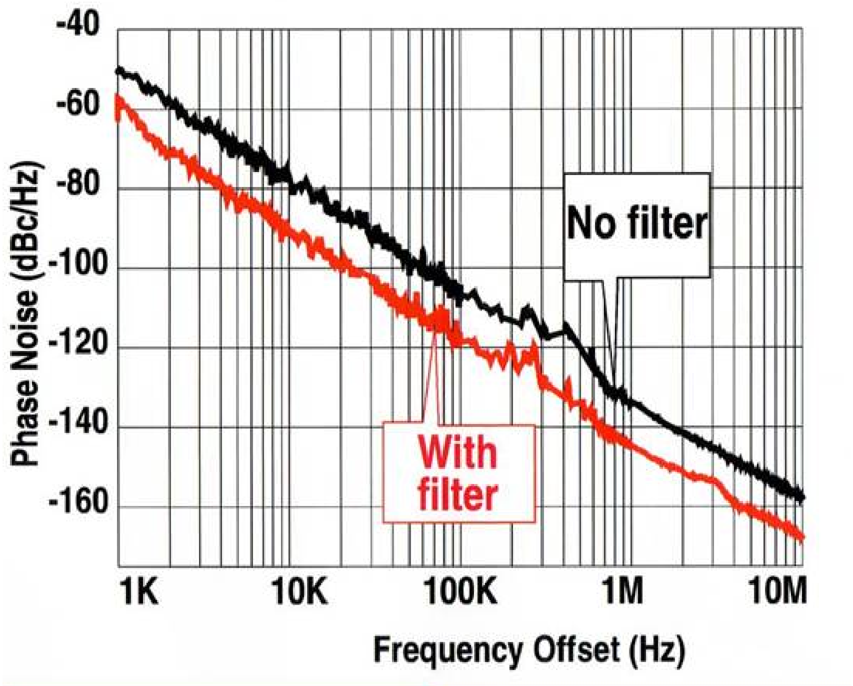
(a) (b) (c)

Filtering of $2f_o$ component in OSC.

Noise filtering of $2f_o$ component reduces the OSC phase noise to -10dB.

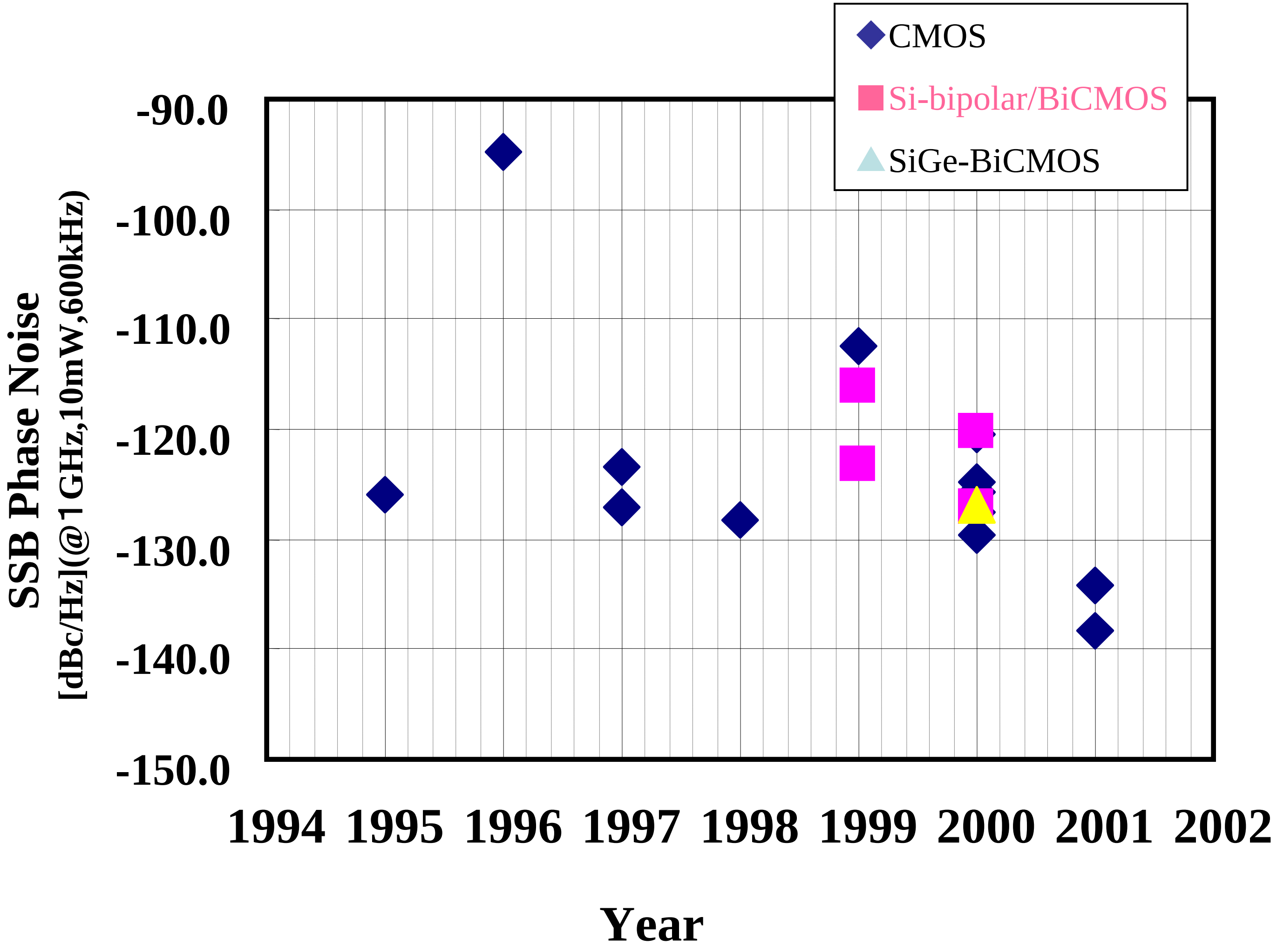
E. Hegazi, ISSCC 2001





Oscillator phase noise progress

Phase noise in CMOS oscillator becomes lower than that of bipolar.



Acknowledgment and references

- **Acknowledgment**

I would like to thank Prof. Asad Abidi in UCLA for his advices.

- **References**

  - Asad A. Abidi, “Power-Conscious design of Wireless circuits and systems,” pp.665-695, “Trade-offs in Analog Circuit Design,” Kluwer Academic Publishers, 2002. (Edited by Chris Toumanzou, George Moschytz, and Barrie Gilbert)
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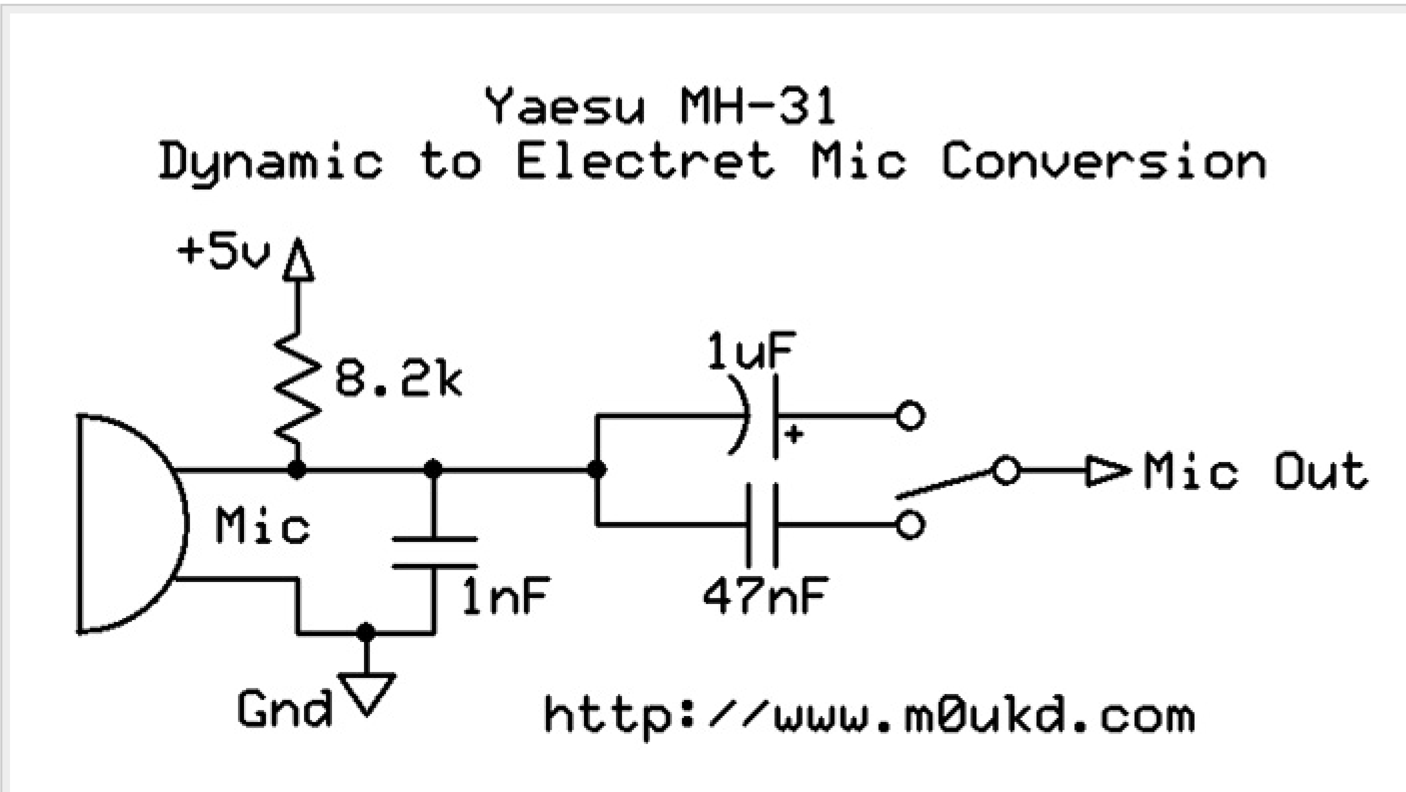
Yaesu MH-31 Electret Condenser Mic Modification

When they built the FT-817, I think its such a shame they did not include a speech compressor. A good speech compressor makes such a huge difference to talk power and average RF power and is very helpful when using only 5w SSB. I did try a 'One Big Punch' speech compressor board that fits inside the MH-31 but I wasnt impressed with its performance, especially the noise gate. I found that with the MH-31 microphone, I have to have the mic gain set to 100 when using SSB and even then talk quite strongly within a few inches of the microphone. Even then I dont think the standard dynamic mic element sounds that good.

One great thing with the MH-31 is that there is an unused 5v supply connection. This allows an electret condenser microphone element to be used in place of the standard dynamic element. I decided to experiment with this, and after some testing I came up with the circuit below.

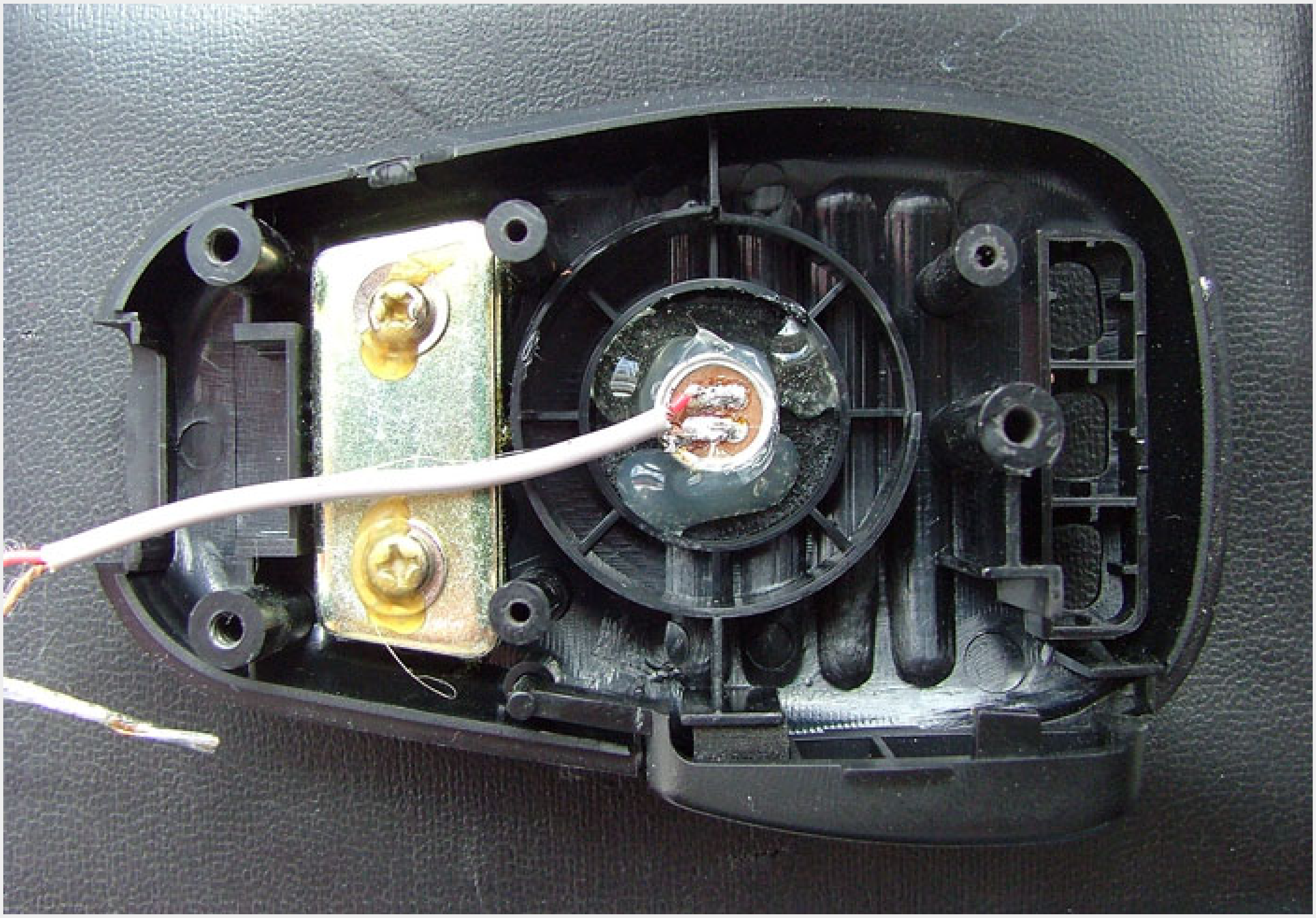


Condenser microphone schematic for the Yaesu MH-31

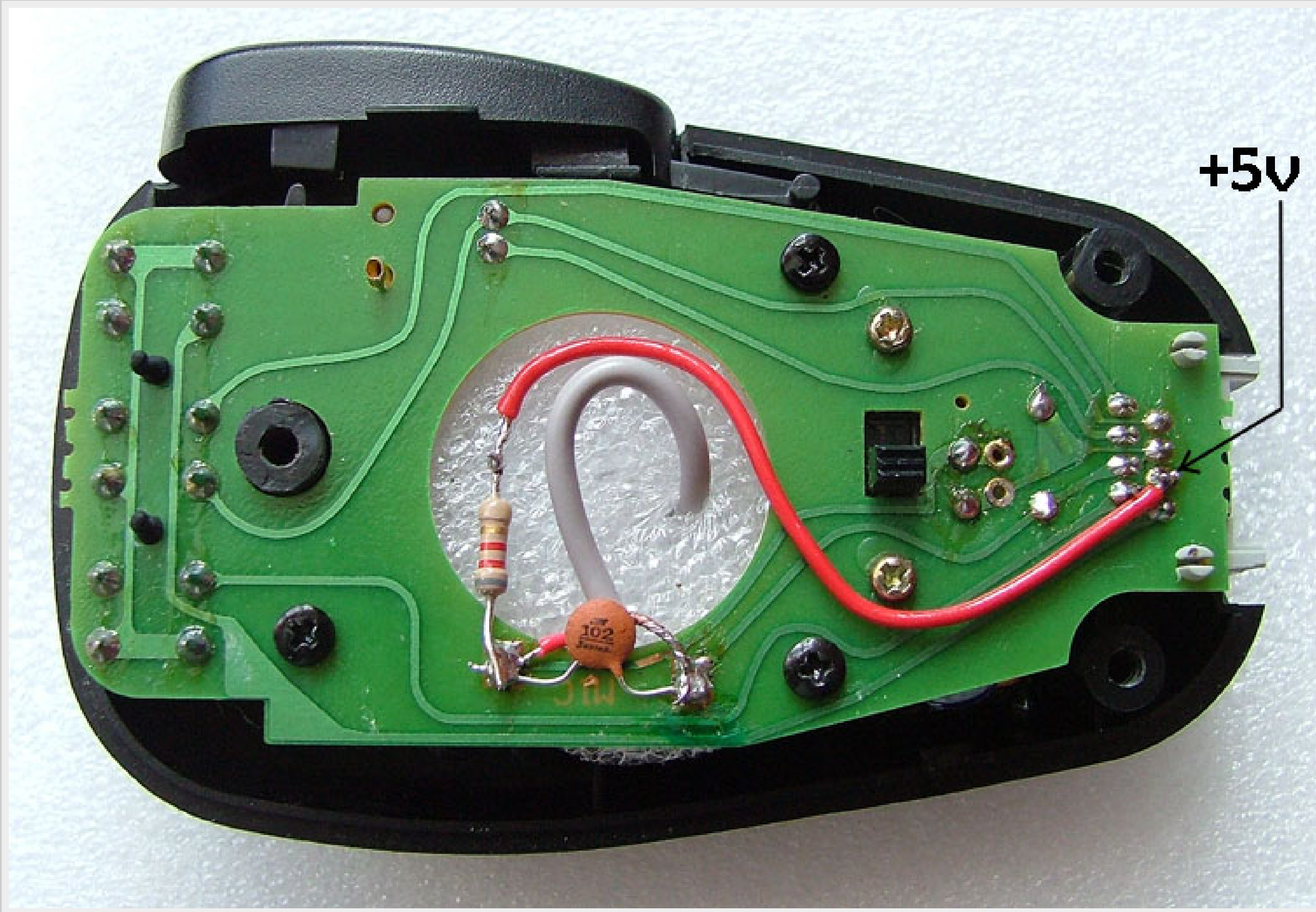
As you can see, I'm still using the tone selector switch as a high pass filter to provide some tone adjustment. I find that the 47nF setting works great for SSB by reducing the low frequency and putting more of the midrange into useful talk power. For FM I use the 1uF setting which provides more full range audio suited to FM 'Rag chewing'. This setup also provides much more mic gain options. With the stronger gain of the electret mic element, I now use between 30 and 40 mic gain on the FT-817 on SSB as well as now being able to talk further away from the mic. I find talking ~6 inches away from the mic much improves voice clarity. Something I found I just couldnt do with the standard dynamic element.

Some photo's are below. I have stuck the electret element onto the front of the mic with some hot glue, then

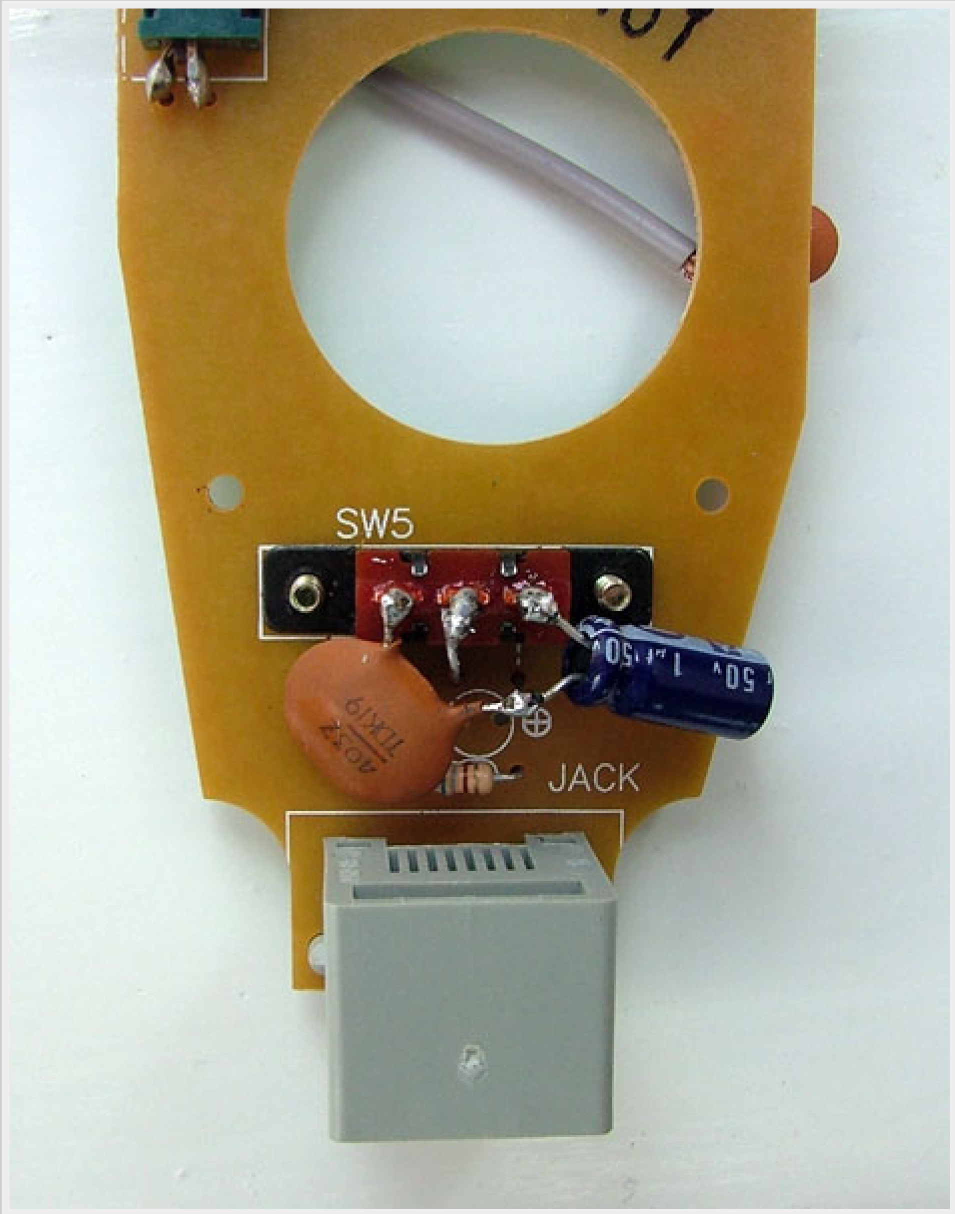
If you seem to share the same issues with the MH-31 microphone, I suggest giving this a go. Please let me know how you think it performs!



Electret element glued in place



The completed modification



Tone switching arrangement

[DIY Audio Home]

Tube power supply PCB with bias supply

For my 815 amp, as well as other projects, I designed a PCB that provides HV rectifiers and filter caps plus an isolated supply that can be used as a negative bias supply.

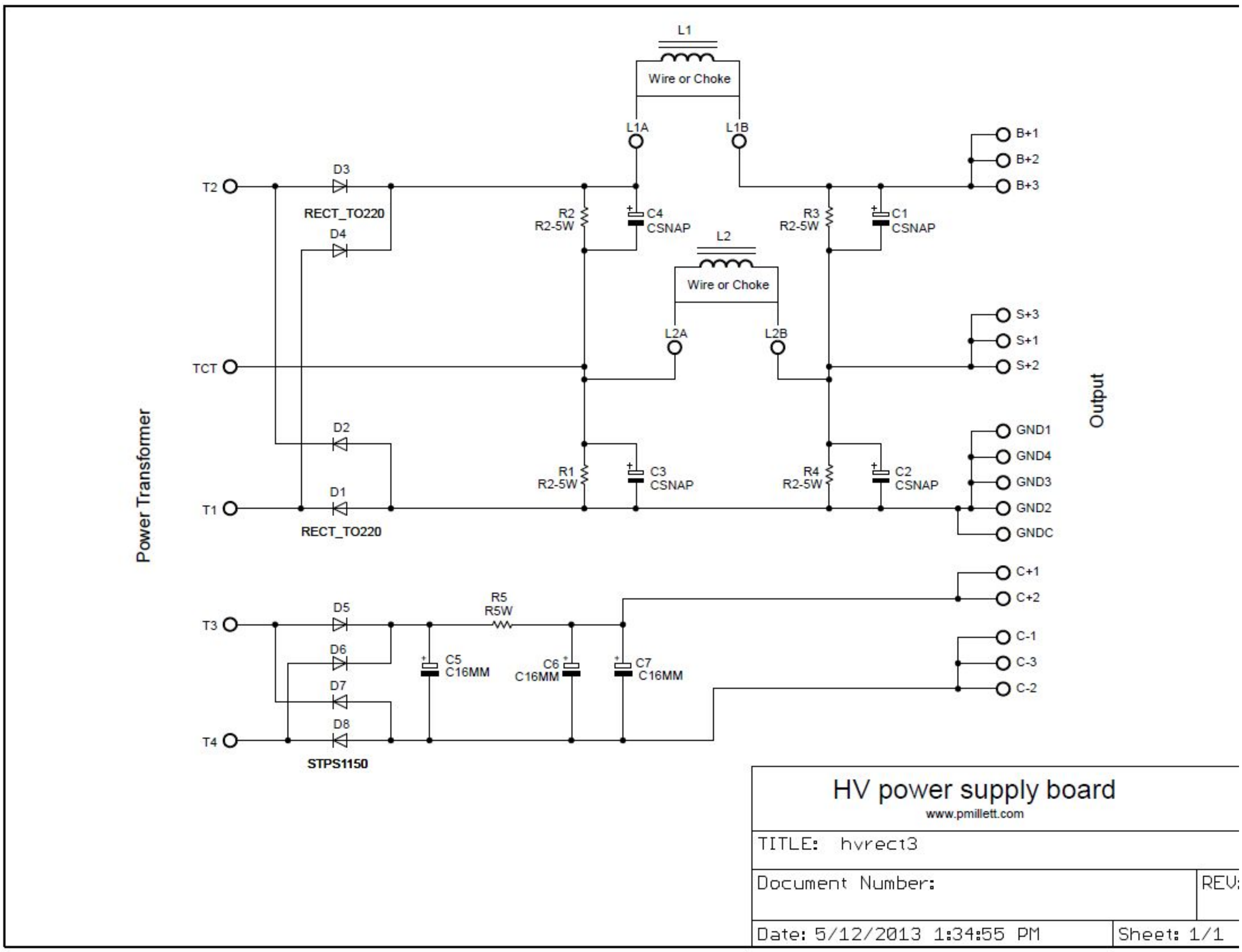
It's pretty self-explanatory. The HV side uses a bridge made of TO-220 rectifiers (I would suggest a SiC Schottky) with a center tap. This provides two voltages, a high voltage, and a lower (roughly 1/2 the high voltage). The filter caps are arranged in series. This allows you to generate a high B+ (for example, 600V) and a lower voltage for drivers and screen supplies.

Pads are provided for chokes in both the B+ and S+ (lower voltage) path. If you don't need a choke you can install a jumper wire.

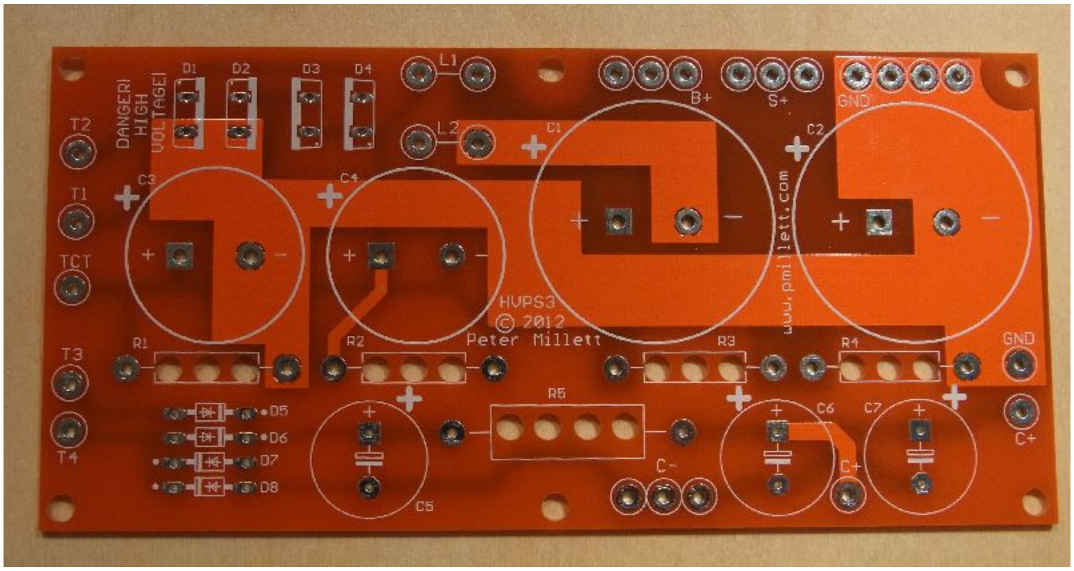
The bias supply is a separate bridge rectifier and CRC filter. There's pads on the PCB to allow you to connect the positive side (C+) to GND, so you get a negative bias supply (C-). You do not have to make this connection, so you could also use it to generate a separate, floating power supply voltage.

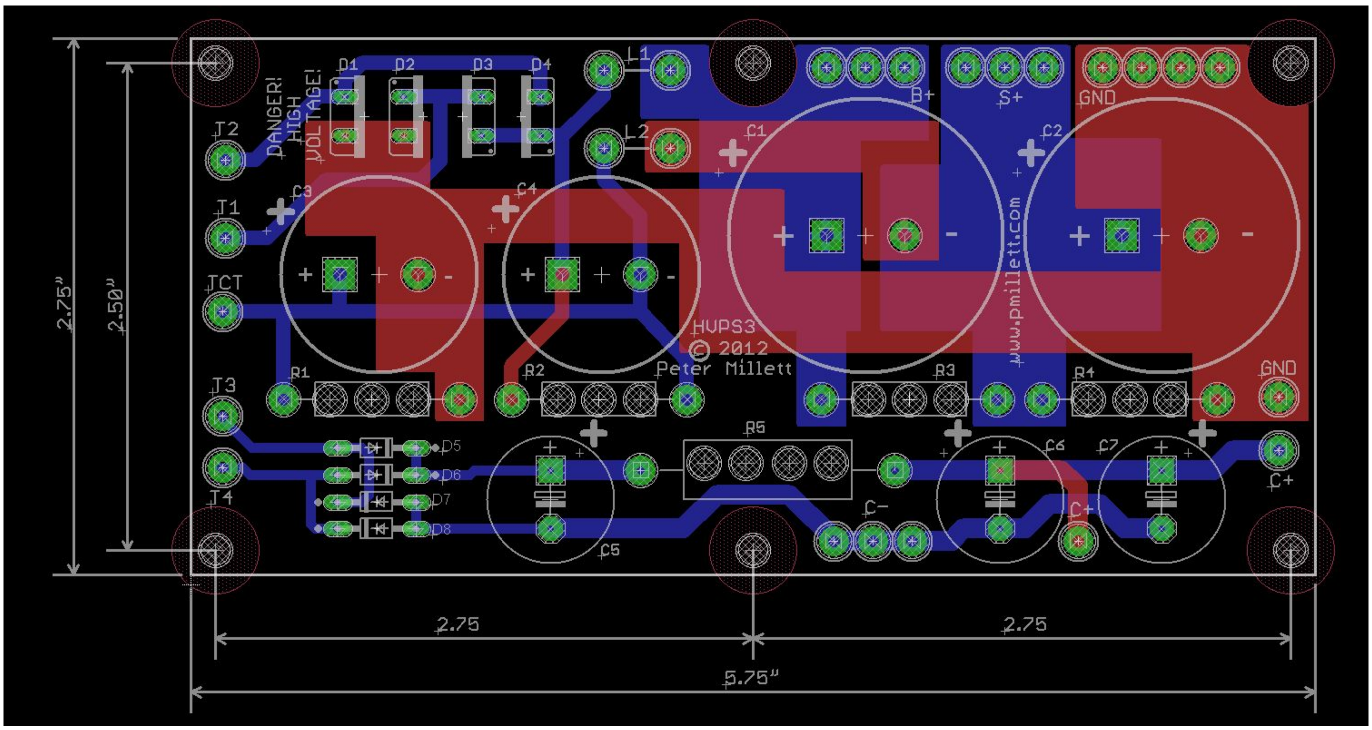
For help designing a power supply, I highly recommend Duncanamps PSUD simulation program. It will help you figure out optimal values for the caps, chokes, and resistors.

Here's the schematic (or download a PDF file):



Here is the PCB, available on eBay:





The assembled PCB:

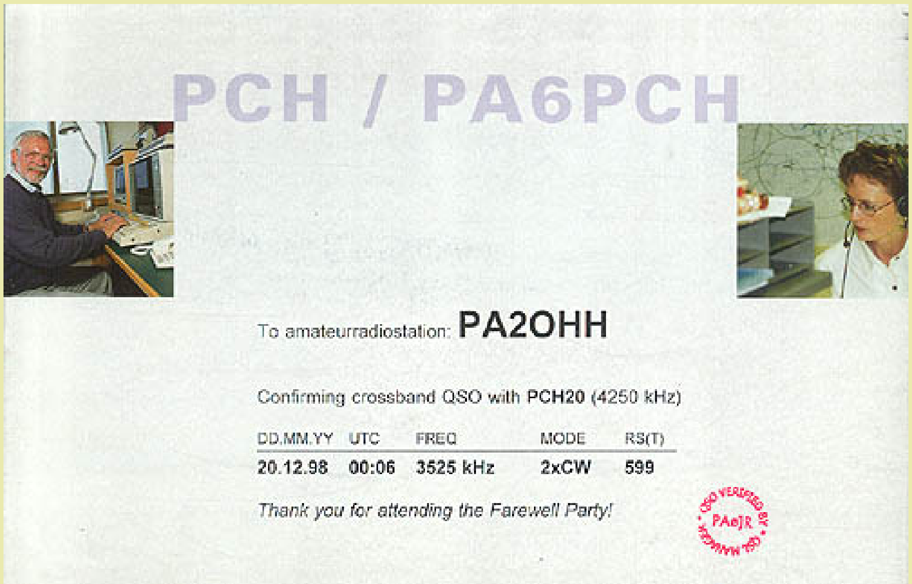
THE DRAKE SSR1 SHORTWAVE RECEIVER

(1977)

The Drake SSR1 shortwave receiver, serial nr 50241.
Frequency stability due to the Wadley loop!

My first shortwave receiver was this SSR1.
The only receiver I had was an old medium wave receiver with tubes that was modified to receive 80 meter SSB amateurs. And then just after my schooltime in 1976, this receiver was in the shop, price was reduced considerably as the S-meter was damaged. It was bought from the first money I earned as a soldier. It became my first all band receiver and gave me the chance to discover all the amateurbands. It has been used intensively in the shack, although it is certainly not the best receiver there is.
It was used for the reception of:

- All the amateurbands and to discover their propagation characteristics when becoming a radio amateur.
- For all 2 meter CW QSO's with a 2 meter converter.
- With my first homemade 80, 40, 20 meter transmitter.
- Satellite communications, transmit on 2 meter and receive on 10 meter.
- Popular medium wave broadcast stations.
- Ship to shore traffic.
- Telex reception of amateurs and commercial stations with a Siemens T100 and later with a computer.
- All kinds of other stations which frequencies were mentioned in magazines.
- To check and adjust oscillators while home brewing.
- As a receiver with all kinds of simple QRP transmitters.



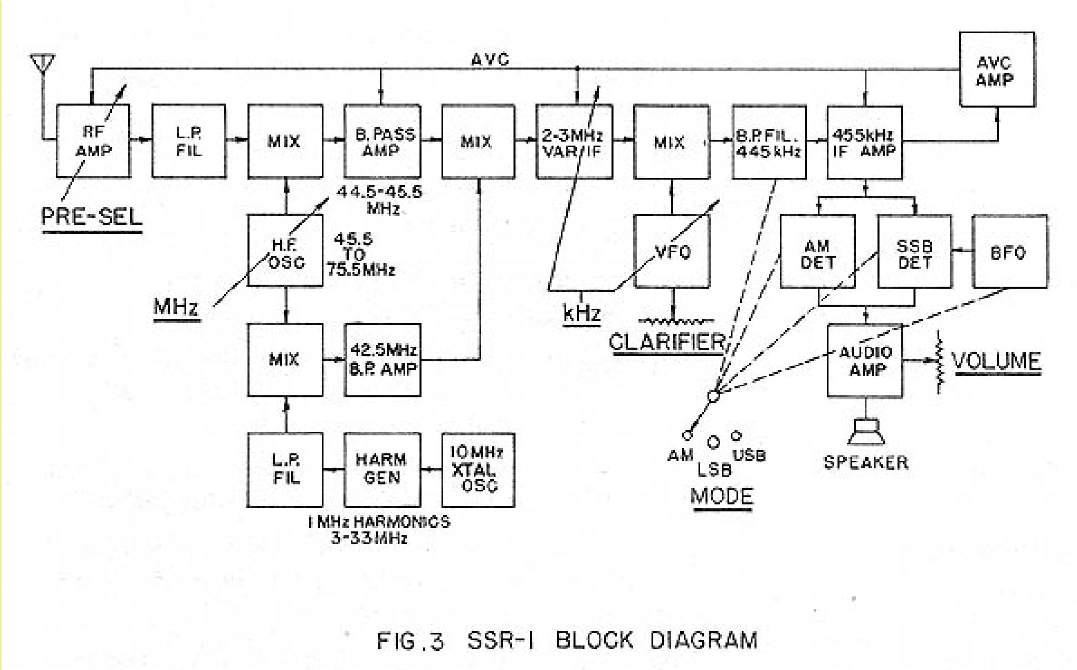
The SSR1 was tuned to 4250 kHz for the QSO with PCH20 during the Farewell party.
I always listened to this CW station when learning CW and later just for fun.
Nice to hear that it transmitted my call... TX was the homemade 80m CW TRX.

Other receivers were more popular.
You will not see this receiver so very often. The newer FRG7 was better and more popular. The Racal RA17 was the best receiver with the Wadley principle but had tubes, it had to warm up, was very big and very heavy.

The newer FRG7 was better and more popular.

The Racal RA17 was the best receiver with the Wadley principle but had tubes

The SSR1 is electronically seen, for 95% a copy of the popular Barlow Wadley XCR-30 portable. The one knob preselector is replaced by a circuit with switches and a variable capacitor. There are some other minor changes like a RF attenuator and a mains supply. It can even be used with internal batteries and telescopic antenna, just as the Barlow Wadley.
Nowadays, I do not use the SSR1 so often anymore as there are two newer home made receivers here, described somewhere else on this site.



Block diagram of the receiver

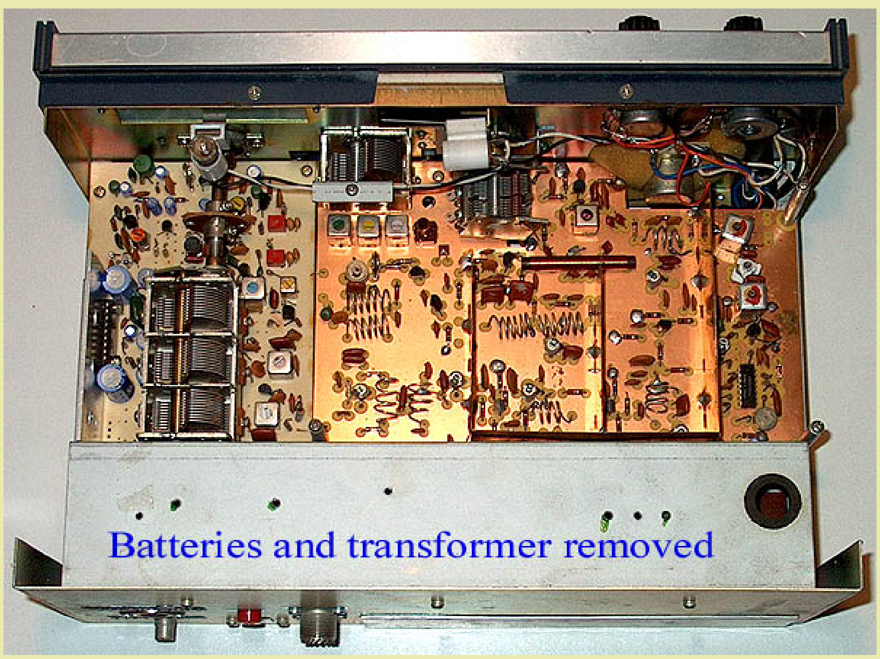
[Click here for the schematic diagram of the receiver]

Explanation of the receiver and the Wadley loop.

In principle, it is a receiver from 2 to 3 MHz. The whole band 0 MHz to 31 MHz is converted to this frequency range in 1 MHz steps.

The Variable Frequency Oscillator (VFO) should be tuned close to 45.5, 46.5, 47.5,......73.5, 74.5, 75.5 MHz, depending on which 1 MHz range between 0 MHz and 31 MHz you want to receive. In passive mixer 1, this desired 1 MHz range is converted to the 1st IF of 45 MHz (44.5 - 45.5 MHz). In passive mixer 2, a harmonic from the 1 MHz harmonic generator is also converted with this VFO signal to a 42.5 MHz amplifier. In the passive mixer 3, this 42.5 MHz signal converts the 1st IF downwards to 2 - 3 MHz, the 1 MHz tuning range of the basic receiver.

If the VFO drifts a little in frequency, the 1st IF and the 42.5 MHz signal do also drift with the same value but the difference (the 2 - 3 MHz signal) will not change! So the stability of the 2 - 3 MHz output signal of passive mixer 3 is only dependent on the stability of the 1 MHz crystal oscillator!



Variable capacitors for the MHz and kHz tuning.
Air coils in the various bandpass filters.

Long wire antenna with the SSR1.
In January during a weekend on the countryside, I could test the SSR1 with a long wire antenna. That was totally different compared to my noisy indoor antenna in the city! It was freezing -6C. It was nice to be outdoors in the freezing cold on the countryside.

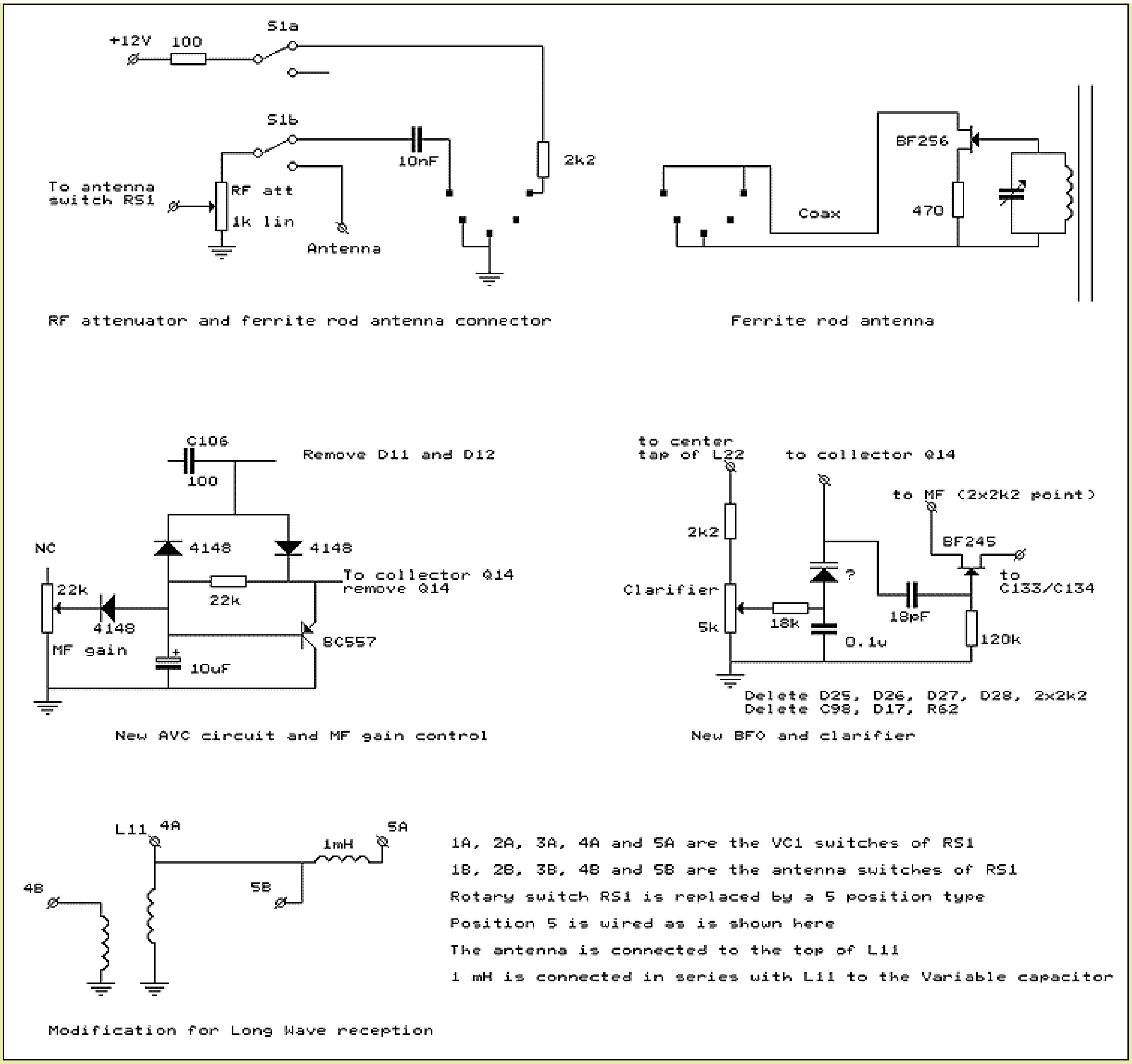
The SSR1
Unfortunately, the new SSR1 did not work due to the cold. We found the problem of the SSR1: the 1 MHz comb generator of the SSR1 was an unreliable circuit and had to be readjusted when it was cold.
When the SSR1 was warmed up, it worked very well with the long wire antenna, although.... In the evening, the SSR1 was overloaded by the strong signals from the long wire, especially on 40 meters. And the 20dB attenuator at the rear side of the SSR1 was or too much or not enough. Later, it was replaced by a variable attenuator at the front side of the SSR1. Also the BFO drifted off the frequency when the temperature changed and had to be retuned then. It would be better to use the fine tuning knob to vary the frequency of the BFO instead of the VFO.

A very pleasant evening
Despite all, we had a very pleasant evening listening to all kinds of signals like the amateurbands, 2182 kHz ship traffic and 500 kHz and others.
The sensitivity of the SSR1 is very good. A disadvantage was that the noise in pauses was just as strong as the CW and SSB signals. Therefore, listening was quite tiring. An IF gain control was added later, so that the sensitivity and background noise could be reduced manually.

Long wave CW beacons
I also wanted to try to receive the longwave CW beacons from the Reeds Nautical Almanac. But the SSR1 could not receive any signals below 450 kHz. Later, the SSR1 was modified so that longwave reception was also possible and spotting the CW beacons became one of the hobbies.

Some modifications where necessary, some were just an experiment.

- The sensitivity is very good, 0.1 uV signals are readable. That is necessary for reception with the telescopic whip antenna but not with the long wire antenna. Intermodulation is -40 dBm, that is quite bad. With the long wire antenna, nothing could be received in the evenings at many frequencies like the 40 meter band. The 20 dB RF attenuator at the rear side of the receiver was not really a practical place... So a potentiometer has been added as RF attenuator on the front side. With 20 to 30 dB attenuation, sensitivity is still good enough and suddenly many stations can be heard on frequencies where you do hear all kinds of noisy intermodulation signals without RF attenuator. Happily the receiver has a preselector at the input and not a broadband filter as modern receivers have.
  The manufacturer did also discover that the receiver performs better when the RF gain is lower. The emitter resistor is 22 ohm in the diagram but was increased to 100 ohm in my receiver to lower the RF gain.
- The 1 MHz harmonic oscillator was an unstable circuit. That was also the reason that the SSR1 did not work when it was cold. It was a 1 MHz RC oscillator that was synchronized by a 10 MHz crystal oscillator. Very often I had to open the receiver and to adjust it because it did not synchronize anymore. I replaced it by a 1 MHz crystal oscillator.
- The gain of the receiver is so high that the noise between speech pauses or between CW characters was just as loud as the speech or CW signal, also because the AVC works quite fast. A potentiometer was added to reduce the MF gain and the AVC was modified. Reception is much more pleasant and less tiring with lower MF gain.
- The BFO frequency was influenced by strong signals. Strong CW signals were unstable in tone height. It was solved by increasing two resistors from 2k2 to 18k. Later a new mixer with a fet was added to the BFO circuit.
- CW signals sounded not good. I replaced the voltage stabilizer by a 7812 but that was not the cause of the problem. The problem was FM modulation of the VFO by the magnetic field of the power transformer. I removed the power transformer and do use an external 12 volt power supply.
- I changed the clarifier so that it controls the BFO of 455 kHz instead of the VFO. It is possible to tune it to the correct position on the slope of the 455 kHz filter when it drifts a litte.
- With a very simple modification (adding a 1 mH coil), it was also possible to receive the long wave.
- Just as with the Barlow Wadley, a connector was made for an external ferrite rod antenna for the medium wave.



Circuit diagram of the modifications.

Performance

The SSR1 is for 95% a copy of the Barlow Wadley. This receiver was designed for portable use. The SSR1 is however always used as a base station receiver. A problem is that the 1st IF is 1 MHz wide, all kinds of strong signals are present and mixed in the 1st IF and the 1st and 2nd mixer. Therefore, dynamic range and intermodulation are not as good as that of a modern base station receiver with a narrow filter after the 1st mixer. Also the side band suppression is not so good and it does not have a CW filter and noise blanker etc.

Stability is good enough for SSB but not as good as that of a receiver with DDS and PLL technology and not good enough for certain digital modes. That is due to the fact that the VFO and BFO of the 2 - 3 MHz basic receiver are free running L/C oscillators. The analog frequency scale is not as accurate as a digital display.

For serious work, you will need a better receiver. But after the necessary modifications, it was always nice to play with this receiver, it is used very often!

The SSB filter curve (orange) and suppressed sideband (green).
Not so good but good enough for many QSO!

[BACK TO INDEX PA2OHH]

"ЖУРНАЛ РАДИОЭЛЕКТРОНИКИ" "JOURNAL OF RADIOELECTRONICS" N 9, 1999

contents discussion

HIGH POWER CONVERTER OF MICROWAVES INTO DC

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Received August 30, 1999

Perspectives of Cyclotron Wave Converter (CWC) of microwaves into DC are discussed in a form of short review. All main parts of CWC (microwave cavity, reverse region and collector) are analyzed. Existing experimental results are briefly described.

1. INTRODUCTION

For many types of wireless power transmission (WPT) systems, diode-type rectenna (rectify antenna) [1,2] is the best (and the simplest) device for back-conversion of microwaves into D.C. Diode-type rectennas have played and play a fundamental role at the stage of principal demonstration of the possibilities of high efficient wireless power transmission by microwaves. However they become not so much attractive for future real high power industrial WPT systems.

Industrial energy systems always demand and use high power and high voltage devices to decrease losses and to increase reliability.

Because of it, we discuss another device allowing to avoid some main negative properties of diode-type rectennas:

- Low power level of single rectenna element,
- Low output voltage and therefore, necessity to connect diodes in series,
- High level of breakdown possibility being dangerous even at rather small levels of microwave or D.C. overloads.

Some our previous experience in microwave electron beam devices [4-6] enabled us to appreciate the advantages and possibilities of improvement of cyclotron wave converters (CWC) [7-30].

2. PRINCIPLE OF CWC OPERATION

Fig. 1 illustrates the principle of CWC operation. Microwaves at frequency ω induce transverse electric field in coupler gap of resonant cavity. The resonator is inserted into external magnetic field B_o. Therefore electron beam, which is formed by electron gun and injected into the resonator, obtains cyclotron rotation at frequency ω_c (a fast cyclotron wave of the electron beam is exited). The resonant cavity is followed by conversion region $(z_1 \le z \le z_2)$, where the external magnetic field is changes in both the direction and the magnitude.

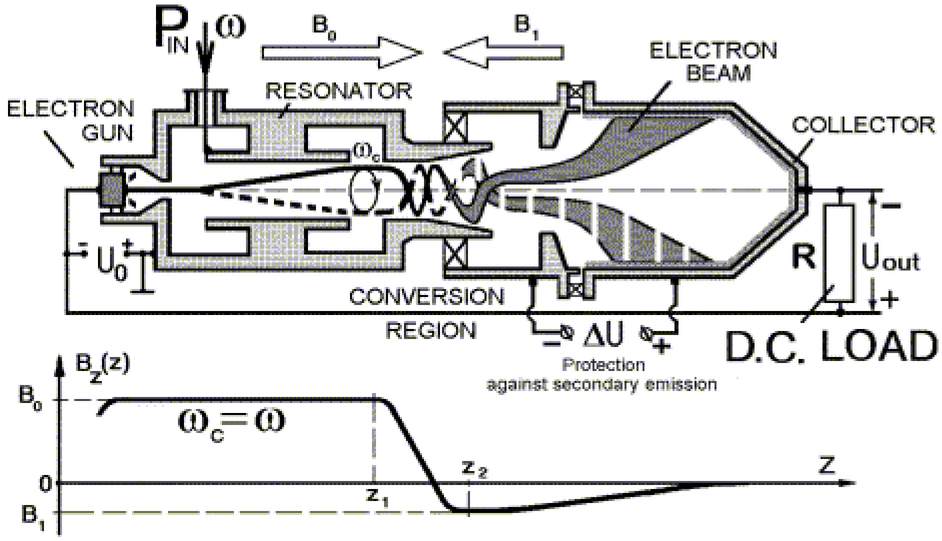

Fig. 1 Scheme of CWC

The longitudinal velocity of rotating electron increases in the divergent magnetic field of the conversion region. Radial component of static magnetic field creates the process when energy of rotation of the electron beam is transferred into the energy of its longitudinal motion. Simultaneously, the electron beam configuration is changed - it takes shape of a spatial helix (energy of fast cyclotron wave is transferred into the energy of synchronous wave of the same polarization).

The accelerated electrons enter collector region, where their kinetic energy is recuperated and transformed into D.C. energy at the load resistance.

High resulting efficiency of CWC is obtained as a result of careful optimization of all main CWC parts. The overall efficiency of CWC can be written as:

$$\eta_\Sigma = \eta_{cav} \cdot \eta_{rev} \cdot \eta_{coll}, \qquad (1)$$

where

η_{cav} - efficiency of microwave energy transfer from external generator (source) into the energy of electron beam rotation in resonant cavity,

η_{rev} - efficiency of rotation energy transfer into additional energy of the longitudinal motion inside reversed magnetic field region,

η_{call} - efficiency of one-stage collector accepting the lowest electron with zero-longitudinal velocity.

3. MICROWAVE CAVITY

The applied energy of microwaves P_ω can be transformed into the energy of electron beam rotation very effectively. For the main type of oscillations the equivalent scheme of such a microwave cavity coupler is simple enough and shown in Fig. 2.

If transit angle of an electron inside the cavity gap is quite large

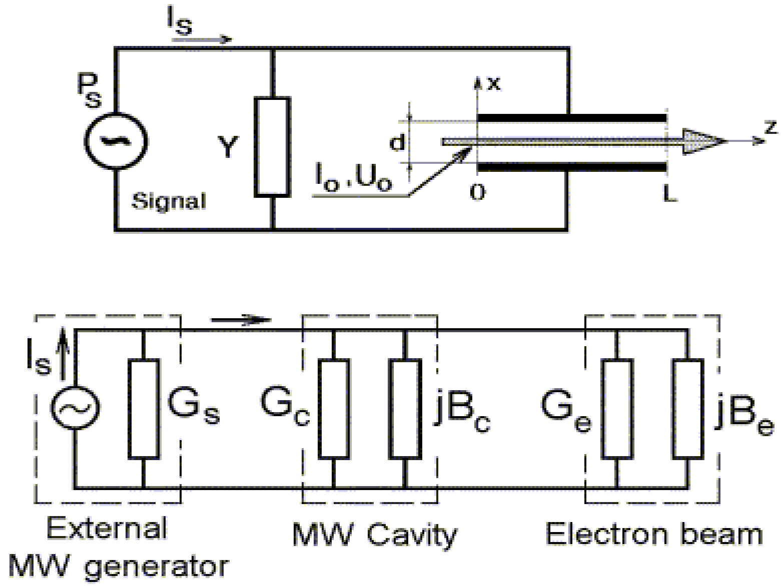

Fig. 2 Equivalent scheme of microwave coupler

$$\Theta_L = \omega \cdot \frac{L}{v_{zo}} \geq 10 \cdot \pi \tag{2}$$

(where L - length of the gap, v_{zo} - longitudinal velocity of the injected electron beam)

the electron beam conductivities (Fig. 3) are [3]:

$$G_e = G_o \left(\frac{Sin\,\vartheta}{\vartheta} \right)^2, \tag{3}$$

$$\vartheta = (\beta_e - \beta_c)L/2,$$

$$\beta_e = \frac{\omega}{v_{zo}},\ \beta_c = \frac{\omega_c}{v_{zo}}.$$

$$B_e = -2G_o \frac{2\vartheta - Sin2\vartheta}{(2\vartheta)^2}, \tag{4}$$

$$G_o = \frac{1}{8} \frac{I_o}{U_o} \left(\frac{L_e}{d} \right)^2 \cdot\ L_e = \frac{\lambda}{\pi} \cdot \sin(\pi \frac{L}{\lambda}),$$

where L_c - length of the cavity; L, L_e - length and effective length of the cavity gap respectively.

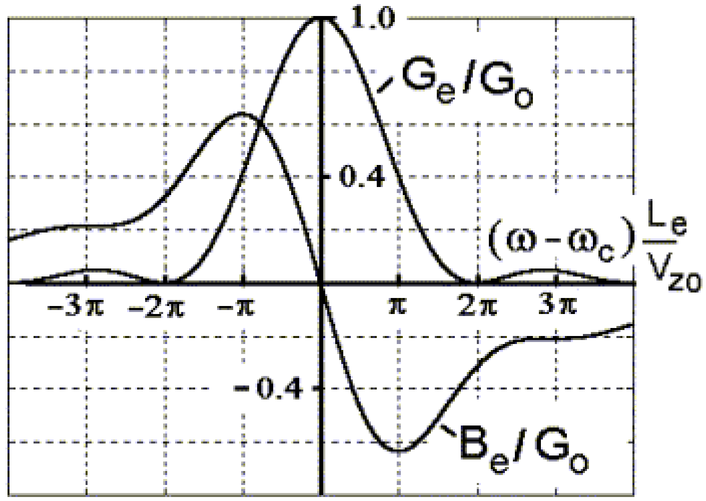

Fig. 3 Electron beam conductivities in microwave cavity of CWC

The efficiency of power transformation from external generator into the energy of electron beam rotation

$$\eta_{cav} = \frac{4G_s G_e}{|Y_\Sigma|^2}, \tag{5}$$

$$Y_\Sigma = G_s + B_c + G_c + B_e + G_e.$$

This is a well-known physical result: all power is transmitted from the external generator into the load when their conductivities are matched in a complex-conjugated way, i.e.

$$Y_s = (Y_c + Y_e)^*. \tag{6}$$

In this case

$$\eta_{cav} = 1 - \frac{Q_{c,load}}{Q_{c,o}}, \tag{7}$$

where: $Q_{c,o}$ - Q-factor of unloaded microwave cavity, $Q_{c,load}$ - Q-factor of the microwave cavity loaded by external generator (without electron beam).

The cavity efficiency of 95-98% is quite available.

2. REGION OF REVERSED MAGNETIC FIELD

As a good approximation, the distribution of static magnetic field may be chosen in the following form [15]:

$$\vec{B} = \left\{ -\frac{x}{2}\cdot\frac{d}{dz}B_z,\ \ -\frac{y}{2}\cdot\frac{d}{dz}B_z,\ \ B_z(z) \right\}, \tag{8}$$

(9)

$$B_z(z) = \begin{cases} B_o, & z \le z_1 \\ B_o \cdot \{1 + C_o + (1 - C_o) \cdot Cos\ [\pi \cdot \dfrac{(z - z_1)}{(z_2 - z_1)}]\}, & z_1 \le z \le z_2, \\ B_o \cdot C_o, & z \ge z_2. \end{cases}$$

Where C_o - parameter of asymmetry of the reverse. For symmetric reverse: $C_o = -1$.

The electron beam of a finite cross-section will be accelerated in the longitudinal direction (Fig. 4) inside the reverse region, i.e. beam rotation energy will be transformed into the energy of its longitudinal motion.

One can write for the efficiency:

$$\eta_{rev} = \frac{\langle v_z \rangle^2 - v_{zo}^2}{v_{o\perp}^2}, \tag{10}$$

where $v_{o\perp}$ - transverse velocity of the beam at the entrance of the reverse region.

Longitudinal velocity spread (Fig. 4) will be exited because of finite cross-section of the electron beam. One-stage collector must accept (not to reflect) the slowest electron of such beam. Because of it:

$$\eta_{coll} = \frac{v_{z,\min}^2 - v_{zo}^2}{\langle v_z \rangle^2 - v_{zo}^2}, \tag{11}$$

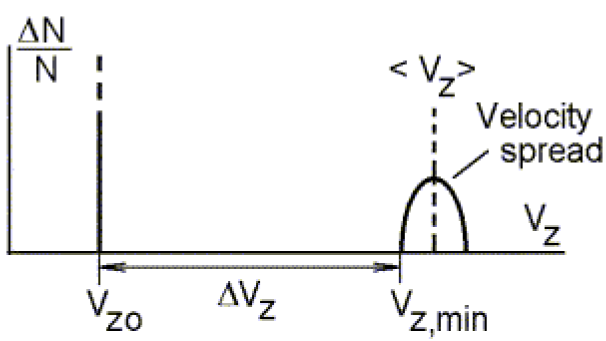

Fig. 4 Electron beam acceleration in reverse region and velocity spread excitation

It is convenient to use the following parameters at the entrance of the reverse region:

$$N_L = \beta_{eo} \cdot (z_2 - z_1) = \frac{\omega}{v_{zo}} \cdot (z_2 - z_1) = \frac{2\pi}{\lambda_c} \cdot (z_2 - z_1);$$ - normalized length of the reverse region,

$$W = \frac{P_\perp}{P_=} = \frac{I_o}{2e} m(\omega_c R_c)^2 / I_o V_o$$ - ratio of the transverse energy to the longitudinal one,

$\gamma = \frac{r_o}{R_c}$ - ratio of the beam radius (r_o) to the radius of cyclotron rotation (R_c) of the beam.

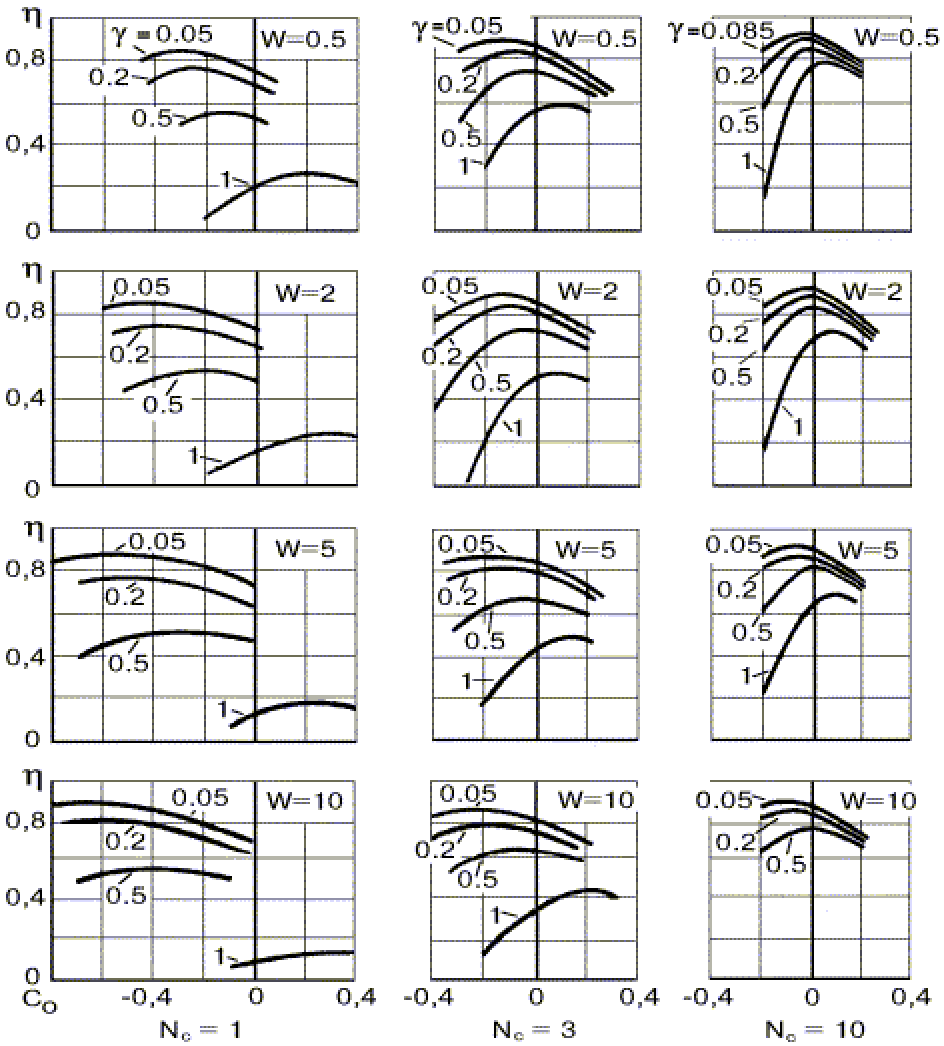

Fig. 5 Results of computer simulation

The results of the computer simulation [15] for the efficiency $\eta = \eta_{rev} \cdot \eta_{coll}$ are shown in Fig. 5.

It is important to point out that practically in all cases the optimal configuration of reversed magnetic field $B_z(z)$ is asymmetric $(C_o > -1)$.

Coulomb forces are not very essential inside the reverse region if the beam current is not exceed 0,5-0,75 of the value of Brillouin current I_{oBr}. (See Fig. 6, where I_{oBr} must be found from the equation $2\omega_p^2(I_{oBr}) = \omega_c^2$, ω_p - plasma frequency).

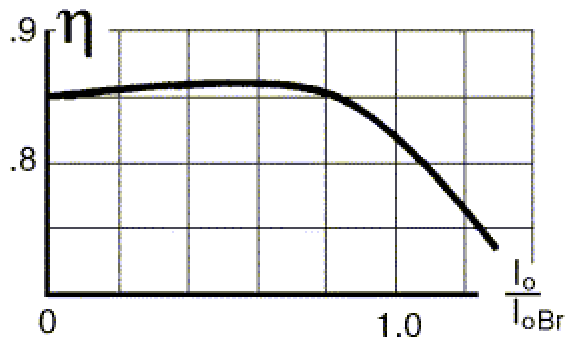

Fig. 6

U_o=10 kV, W=2, N_c=3, $\gamma = 0.2$

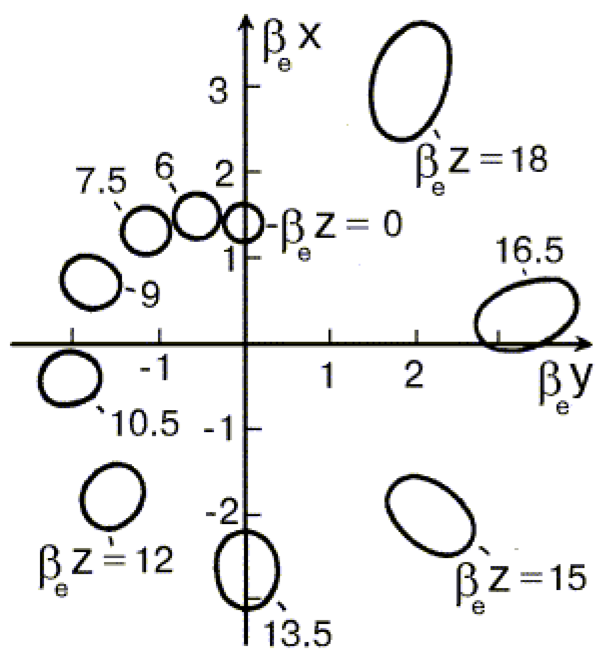

Fig. 7 Electron beam cross-sections inside the reverse region

U_o=10 kV, W=2, N_c=3, $\gamma = 0.2$

The increasing beam displacement inside the reverse region (Fig. 7) must be also taken into account under development.

5. COLLECTOR

Heat rejection and protection against secondary emission are the most important problems of the CWC collector. The potential of collector surface is much lower then the potential of CWC microwave cavity. Such electric field will stimulate the back-motion of the secondary electrons.

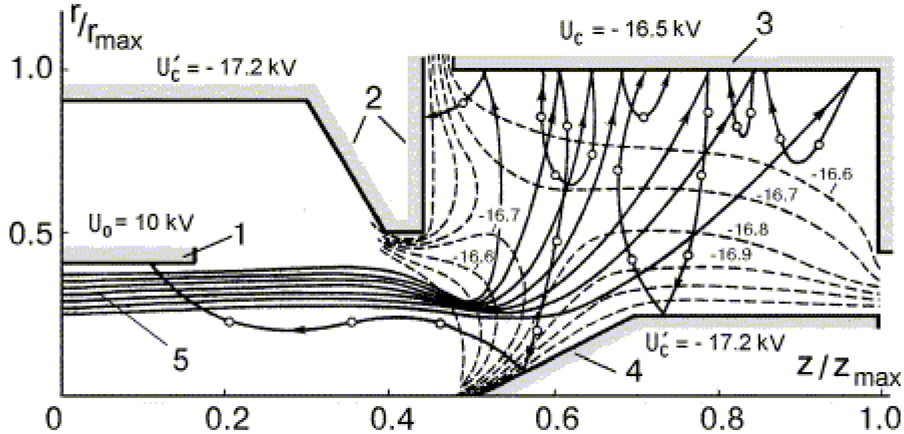

Fig. 8 An example of computer simulation of CWC collector with additional electrodes (2,4) forming electric field protecting against secondary emission
1 - cavity's potential electrode,
3 - surface of the collector accepting primary beam, 5 - incoming primary beam (Model included 48 primary elementary beams and 48 secondary beams)

To solve this problem it is necessary to use a special secondary emission protecting coating of the collector surface. Besides, the additional electrode (Fig. 1,8,9) can be effectively used to create a local electric field protecting against back-motion of the secondary electrons.

The formal computer simulation of the collector area [17] is practically the same as for another microwave conventional devices (Klystrons, TWTs, etc.) with collector of a depressed potential (Fig. 8).

At normal operational mode practically all beam current reaches the collector surface (Fig. 9). A small current of primary (and maybe secondary) electrons forms (by $R_o^{'}$) a negative potential of the additional electrode of collector region.

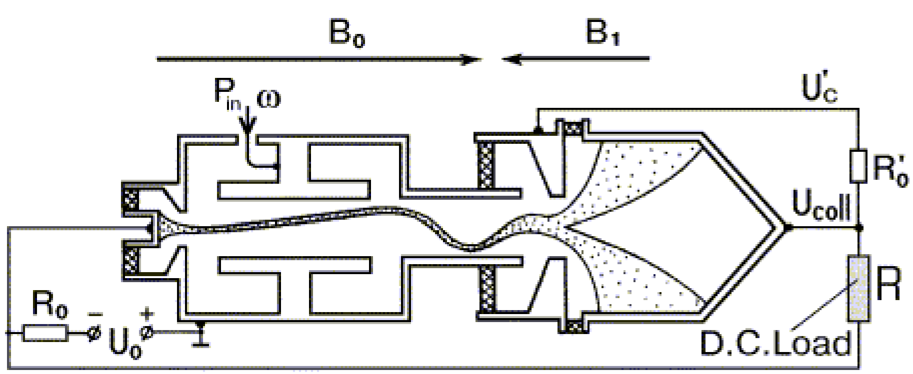

Fig. 9 CWC with simple additional electrode

If input signal is smaller or larger than the normal one a part of beam current is intercepted by the cavity. Using $R_0 >> R$ we can solve the problem of CWC protecting against microwave or D.C. overload.

6. PRELIMINARY EXPERIMENTS

The first CWC experiment by D.C.Watson, R.W.Grow and C.C.Johnson was carried out at power level of 1-1.5 W [7-9], i.e. like power level of a single diode-type rectenna element. The efficiency of 56% has been achieved.

At Moscow State University a version of CWC was also tested (Fig. 13). The efficiency of 70-74% at power level of 25-35 Watts was demonstrated (Fig. 14).

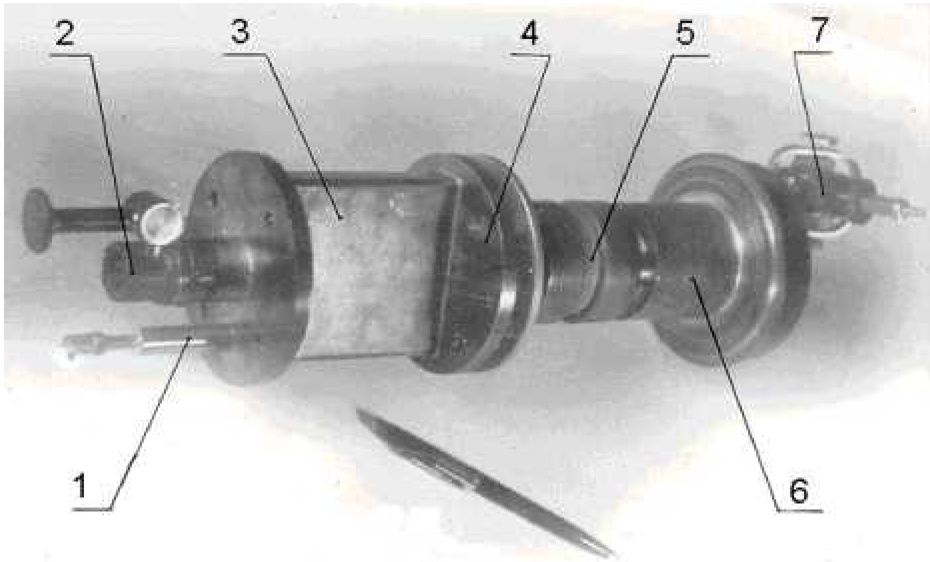

Fig. 13 1 - MW input, 2 - electron gun, 3 - microwave cavity, 4 - a part of magnet system, 5 - isolator, 6 - collector, 7 - pump

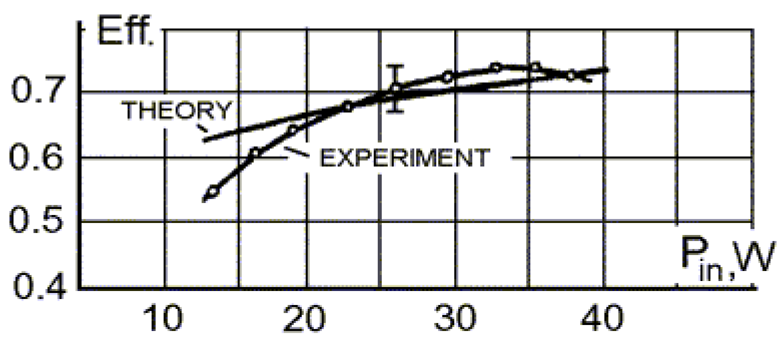

Fig. 14 Efficiency of CWC by theory and experiment

The Tory Research and Production Corp. (V.K.Rosnovsky, K.I.Sigorin and colleagues) in collaboration with Moscow State University created and tested several high power CWC, Fig. 15. The efficiency of 60-70% up to 83% have been demonstrated at microwave power level of 10 kW and output D.C. voltage of 15-20 kV.

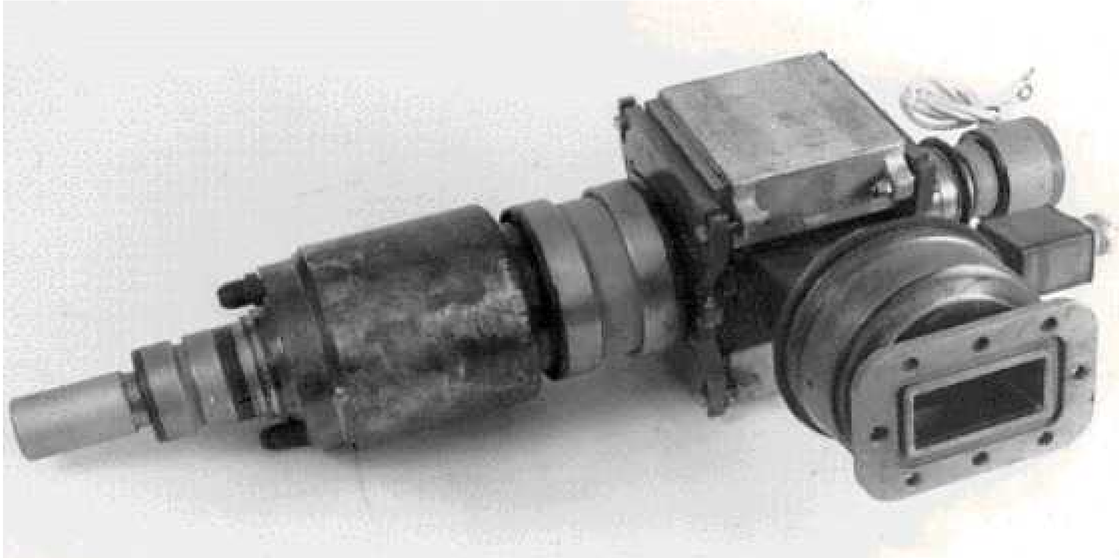

Fig. 15 High Power CWC of Tory Corp.

The Istok State Research and Production Corp. (Yu.A.Budzinsky, S.V.Bykovsky and colleagues) started in the development of CWC. An intermediate version of CWC (Fig. 16, Fig. 17) was shown at WPT'95 Int. Conference in Kobe (Japan).

Fig. 16

Fig. 17

Preliminary version of CWC of Istok Corp,

7. DISCUSSION

In conclusion, using existing theoretical and experimental results it should be summarized the optimal parameters of CWC:

Output power range, kW	0.5 ... 50
Conversion efficiency, %	
possible	85 ... 90
demonstrated up to	83
Output voltage range, kV	1 ... 50
Frequency range, GHz	1...10
Bandwidth, %	0.5 ... 5
Focusing system	permanent magnet

The main advantages of CWC are:

- **High conversion efficiency**
- **No breakdown problems**
- **High power level**
- **High reliability**
- **High output voltage**
- **No higher harmonic re-radiation problems**

Existing preliminary experiments performed at the frequency of 2.45 GHz have confirmed the main physical ideas of CWC. Nevertheless, the real CWC-devicesacceptable for microwave energy transmission systems must be developed yet.

CWC may be preferable in different types of Microwave Power Transmission Systems (MPTS), including future Space Power Satellites (SPS) and ground-based MPTS (Fig. 10-12). Some types of mirror concentrators will be necessary to use CWC effectively.

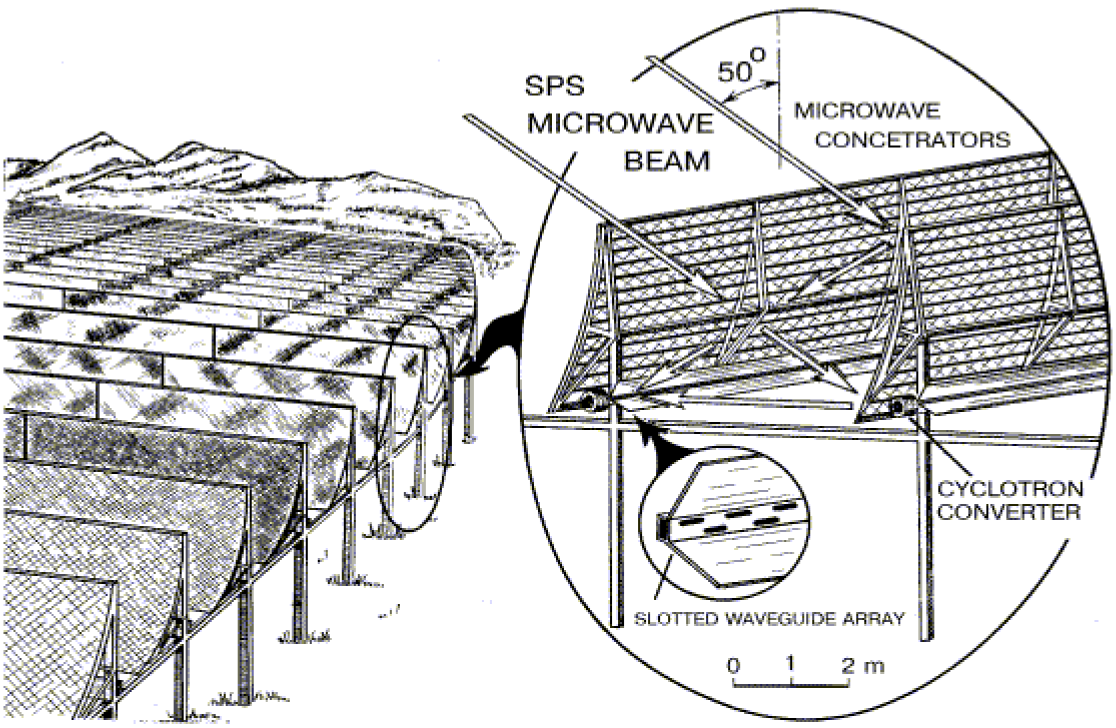

Fig. 10 Schematic illustration of receiving system with CWC for future SPS

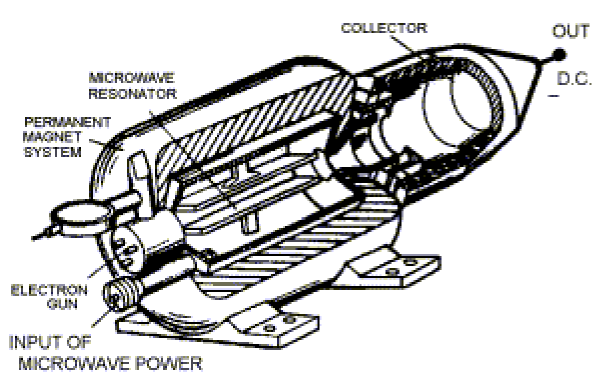

Fig. 11 Schematic illustration of a CWC

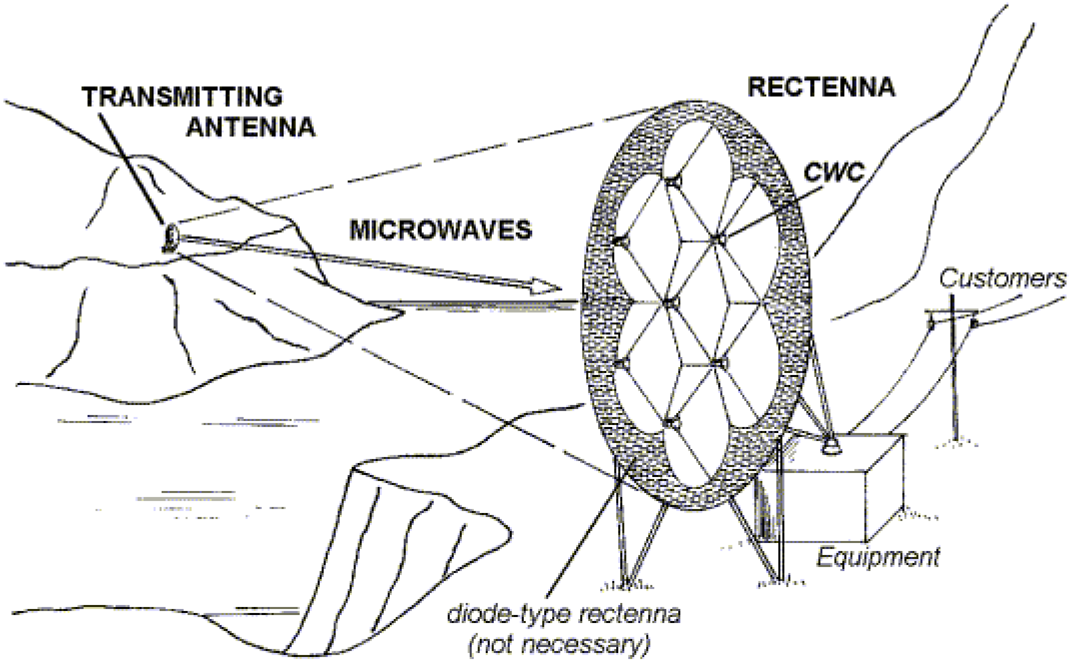

Fig. 12 Schematic illustration of ground-based MPTS with CWC

CWC is a new device of microwave power conversion into D.C. The motivation of developing the CWC was originally to invent an efficient power converter on a ground receiving site for the Solar Power Satellite (SPS). However is also applicable to many other occasions where microwave power transmissions of high density of electric power is necessary, such as non contact wireless power transmission in factories and for power feeding to electric vehicles.

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Portable PVC Antenna Mast

By: Eli & JW

26 November 2002

1st time it was up.

On my recent trip to New York I ran across a ham operator on the Coast Guard base. We got talking about different things and he told me about a ham who's in a club with him. He told me about making a tower out of PVC pipe. He drew a rough sketch for me so I could get the idea. Looked pretty cool. After I got home from NY I ran the idea by JW and we decided to build one. We added some new ideas to it and started building.

When the mast is completed you will have a 20' mast guyed at its top and midsection in 3 directions. It will be capable of supporting a lightweight antenna such as a J-pole, small beam or solid dipole. It's not designed to withstand a lot of wind or large antennas.

You're more than welcome to make it taller, but it's not recommended.

Parts list for a 20' mast:

2 pieces of 1 ½" schedule 40 PVC pipe

3 male 1 ½" threaded couplings

3 female 1 ½" threaded couplings

1 1½" tee

1 1½" to 1" reducer (glue on)

1 1" Pipe cap(female threads)

Small can of PVC cement

2 100' length coils of clothesline rope or equivalent

3 large stakes for guy ropes

2 plastic or aluminum guy plates (see note)

NOTE: Guy brackets are recommended for use of a small directional antenna to ease in turning mast to aim antenna. If not used, then you must tie guy ropes directly to mast. Pictures are later in article.

If you decide to use the brackets then the following materials are required:

1. 5 5/8" by 5 5/8" by 3/16" aluminum plates

Recommended tools:

Hacksaw

Tape measure

Knife

Cigarette Lighter (fuse the end of your guy ropes if synthetic rope)

Hammer; maul; rock; club(somethin' to drive guy stakes with) We used RxR track.

Any other tools you may need to mount the antenna

If you decide to use the brackets then the following are required:

2" hole saw

3/8s drill bit

Drill

De-burring tool, sandpaper, file or dremel tool to smooth edges

Bench vise and hammer. Or some means of bending metal.

Ok, let's start building…. the fun begins

Cut both pieces of PVC pipe exactly in half. (There is still one more cut to be made, more on this later)

There is some counsel necessary when it comes to working with PVC cement. Heed the advice from those who have screwed up and had to buy new parts. Not to mention any names….

Once the PVC cement is applied it will start to set in approx. 10 seconds and WILL be set in approx. 15 seconds. This may not sound like much time, but it is sufficient as long as you planned properly. The 7 P's= Prior Proper Planning Prevents Pi$$ Poor Performance. Read the instructions on the can of cement that you plan to use. Different manufacturers have different recommendations.

Make sure to keep cement off from all threaded surfaces and anything that you don't want glued. Once glue is applied it is PERMANENT.

This is the pictorial procedure for gluing all PVC pipe, couplings, fittings etc. regardless of the application. The steps in constructing the mast follow.

Apply glue to pipe Apply glue to coupling

NOW VERY QUICKLY

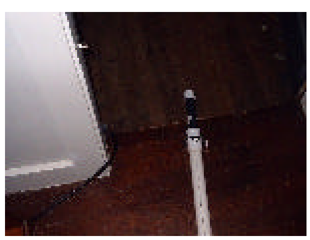
Twist coupling onto pipe Hit it with your hand to seat coupling

This must all be said & done within 10 seconds!!!!

Now, let’s look at the mast laid out on the floor, loosely assembled. Just so you get the overall picture of the final product.

Bottom showing "T" fitting Mid- section showing guy bracket

Top w/ guy bracket & reducers View from top to bottom

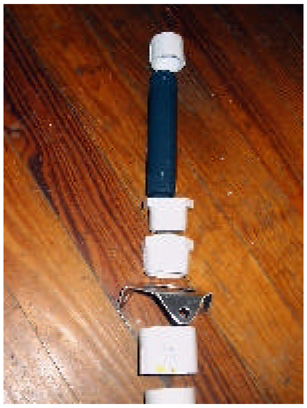
Lay your parts out on a flat surface. Starting from the top and going to the bottom they must be in this order.

- 1" plastic pipe cap
- 1" pipe nipple (6" long)
- 1" to 1 ½" reducers
- Guy bracket
- 1 ½" threaded female coupling
- 5’ pipe

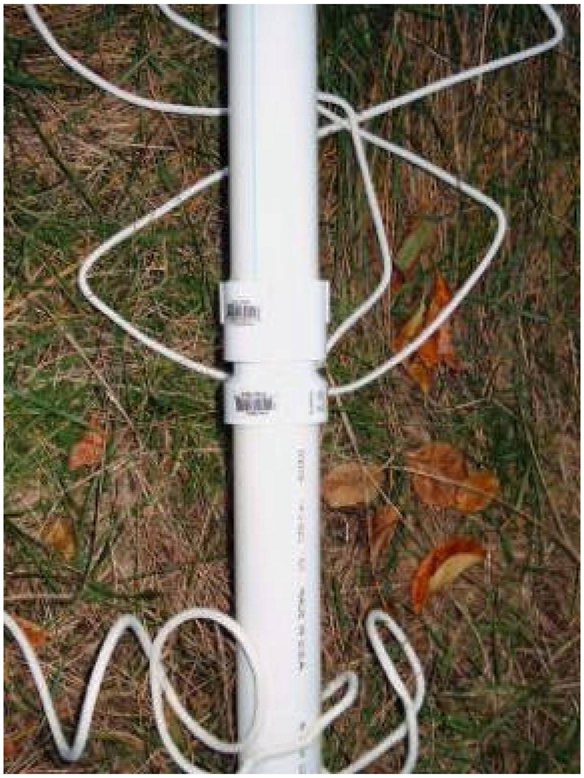
- 1 ½’ threaded female coupling
- 1 ½ threaded male coupling
- 5’ pipe
- 1 ½" female coupling
- Guy bracket
- 1 ½" threaded male coupling
- 5’ pipe
- 1 ½ threaded female coupling
- 1 ½" threaded male coupling
- 5’ pipe (Here’s the "extra cut" we mentioned). Cut 3 ½ inches off the bottom most end. This keeps ALL parts the same length for packing & transport. Finally:
- 1 ½" TEE

DRY fit everything together to make sure everything fits well. Now glue the fittings on…ONE GLUE JOINT AT A TIME!!!

Here’s a couple "detail fotos"



Exploded view of top



Assembled joint

Male threads should be facing UP whenever possible to prevent water from getting into the threads and possibly freezing. Shown in "Assembled joint" picture.

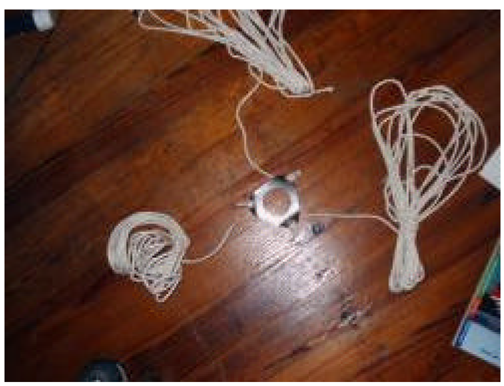
The purpose of the Tee joint is to allow coax to run down the interior of the pipe and surface at the bottom without the weight of the mast sitting on it.

The reduction to 1" pipe at the top is to allow a small beam to be mounted with the use of standard "U-bolts". The reducers that we used were locally available to us. Due to your location specifications may vary, but you get the idea.

When all of the cuttin' & gluin's done, here's what you should have:

WHA-LAA!!!!!!!

One last item to manufacture…da guy ropes. You will need 3 sections of rope cut 30' long for the top guys. You will need 3 sections of rope cut 25' long for the mid guys. Tie the guys directly to the mast or to the guy brackets if used.

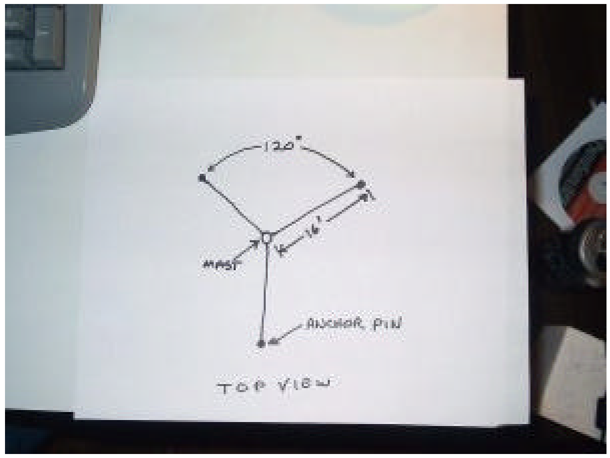


Guy ropes on bracket Close-up of the same

JW has a friend who is handy with aluminum. We custom manufactured these brackets. 2 ½ hole in the middle, 3/8's holes for the guy ropes. The bends are approx 45 degrees.

Now, let's erect this puppy!!!!

This takes at least 2 people to erect. 3 would be ideal. Find a clear flat area approximately 35' in diameter. Decide where you want the mast to set. Measure out by the following approximate dimensions and set 3 guy stakes/anchor pin.



Where guy placements should go

Measure approx 16' out from where the bottom of the mast will be in 120 degree intervals.

Mast ready to go up

Lay out the guy ropes in their respective direction. Attach 2 of the top guy ropes to 2 stakes. The mast must be completely assembled and laying on the ground with the top FACING the 3rd stake. The antenna & coax must also be installed. Nothing is tied off to the 3rd stake yet.

JW tryin' to look busy!

1 person pushes the mast toward the 3rd stake and pushes upwards at the same time using the 2 guy ropes that have been tied off at support for the top of the mast. Don't try and tip this thing up. You NEED to use the 2 guys to your advantage. If you just try and tip it up, it will break!!

As the 1st person pushes the mast up the 2nd person holds the 3rd top guy rope. When the mast is vertical, it's the 2nd person's

responsibility to hold tension on the 3rd rope. THIS IS CRITICAL!! If the 2nd person fails to hold tension, the mast will fall over backwards. Also, as soon as the mast is vertical, the 2nd person pulls SLIGHT tension and ties off the guy rope to the 3rd stake. The 1st person stays at the mast to hold it. The 2nd person is the one who runs around and ties the mid-point guy ropes and makes any adjustments.

During the "standing up process" the mast will flex. It’s only PVC pipe. A little flex is ok, just ensure that it doesn’t start looking like a fishing pole with a 15 lb fish on it and you should be fine.

JW and I set this up in 15 minutes on my front lawn

See the J-pole "copper cactus" in the top?

Coax coming out of the Tee joint

We know you can buy a collapsible 35’ mast at Radio Slack all pre-assembled for about $35-40 bux, BUT can you fit that in a small vehicle?….didn’t think so. Being only 5’ long this will fit in just about any trunk! :o)

Well, that’s pretty much all there is to it. Get creative and paint it. Cammo would be cool! Again don’t overload it and try to stick a HF beam on top or try and use it during a hurricane. Common sense prevails. Have fun & happy HAMMING!!

Be safe and stuff.

Eli & JW

SIMPLE PC RECEIVER WITH THE MICROCONTROLLER DDS

(2003)

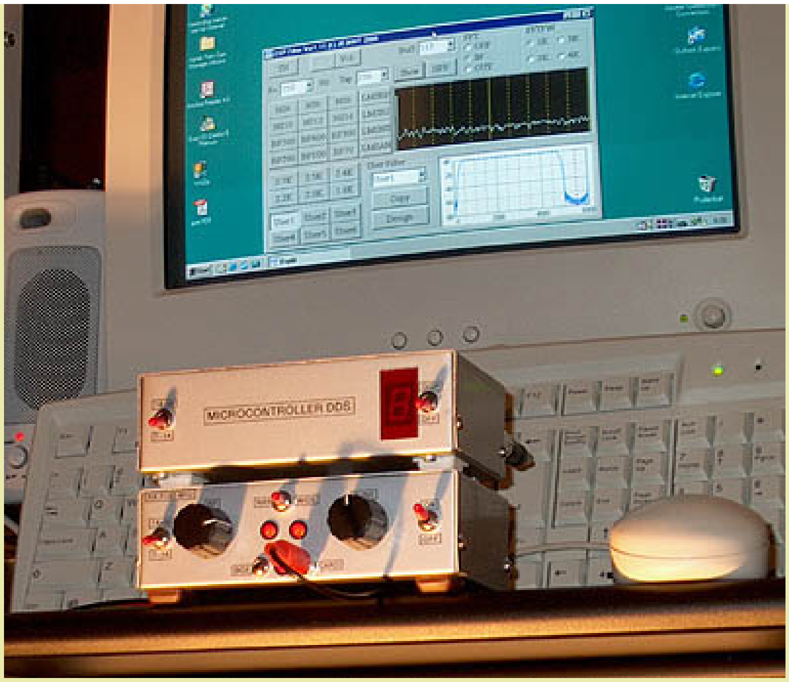
KLIK HIER VOOR DE NEDERLANDSE VERSIE

Simple direct conversion Shortwave PC receiver with the microcontroller DDS.

Shortwave PC receiver 7-30 MHz with the ingenious simple microcontroller DDS
This PC radio can be used in two different ways:

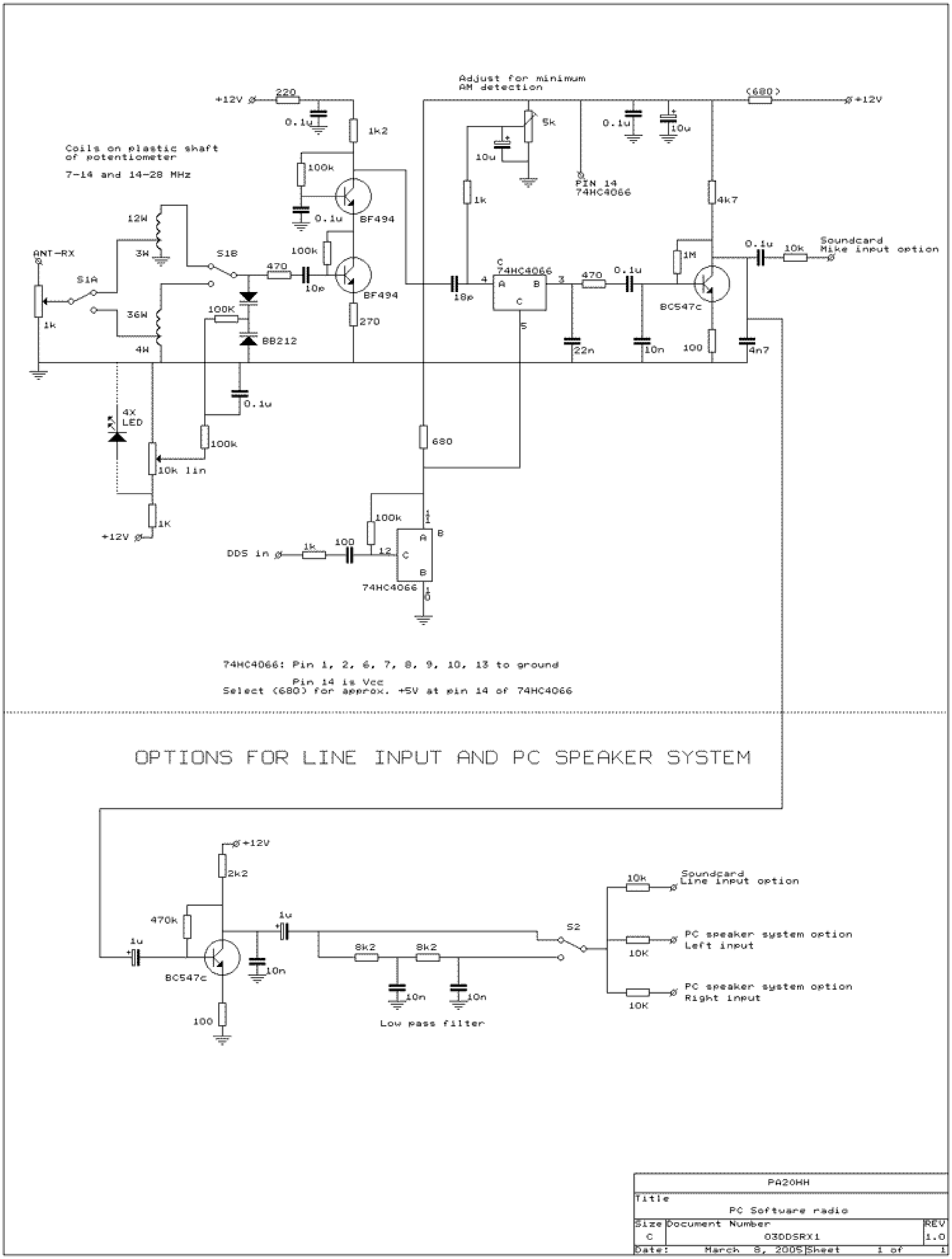
- Connected to the souncard of the PC
  Audio filtering is done by free DSP software with available bandwidths from 100 Hz to 4 kHz.
  Decoding of digital modes is also possible with free decoding software.

- Switch off the PC and connect the receiver directly to the soundsystem (boxes with amplifier) of the PC.
  Listen in wide band mode, all signals from -8 kHz to +8 kHz can be heard.
  Or switch on the 2.5 kHz low pass filter for more selectivity.



PC radio connected to the soundcard.
DSP software does the audio filtering.
A lot of digital modes can be decoded!

Wideband audio
Normally we use narrow filters to receive only the station with which we have a QSO. But with this receiver we can also listen in wide band mode. All signals in the band -8 kHz to +8 kHz can be heard. It is very nice to hear all the activity in such a wide audio band and to select certain stations just by ear and "brain DSP". I use it as background sound in the shack or when working with the PC. It sounds great, all these different strong and weak signals, coming on the band and leaving their frequencies later.



The Direct Conversion receiver

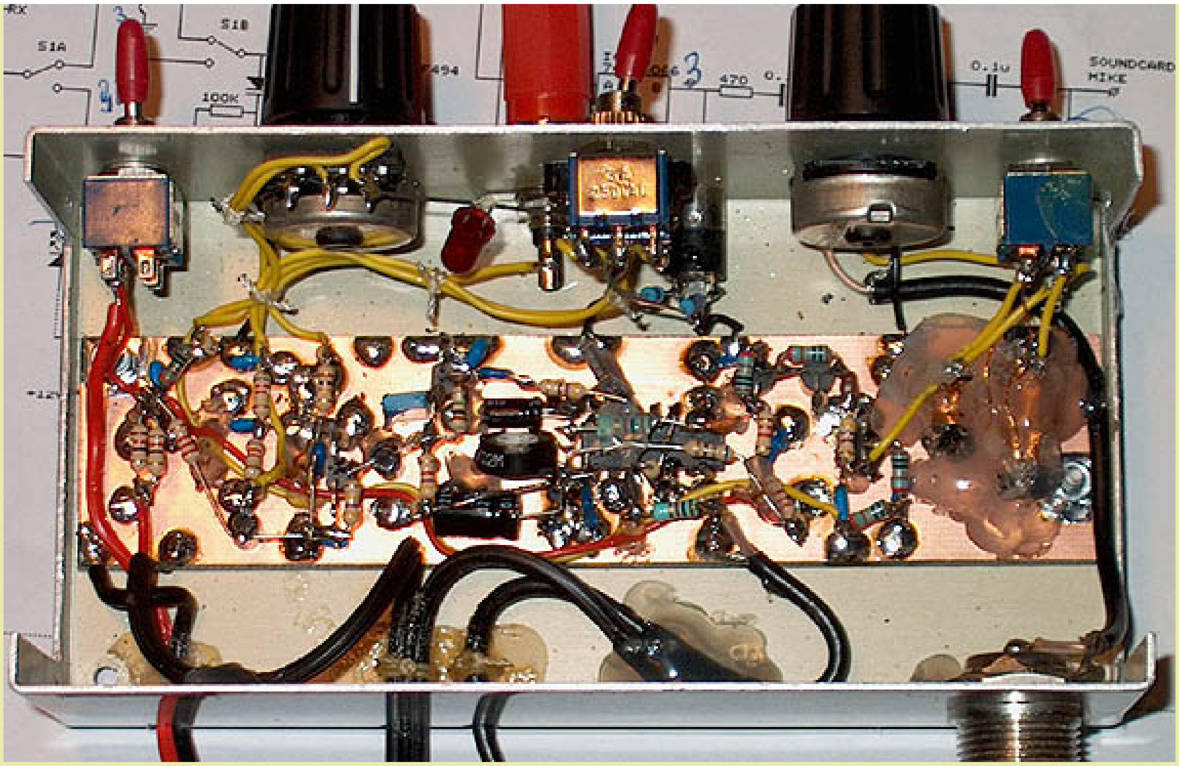
The Direct Conversion receiver.
[big diagram]

The Direct Conversion receiver
At the input we start with a potentiometer of 1 k ohm, it is the RF attenuator. The next circuit is the preselector, switchable to the ranges 7-14 MHz and 14-30 MHz. Tuning of the preselector is done with a potentiometer. The tuning voltage is stabilized by 4 LEDs but of course you can also use a 6.8 V or 8.2 V zener diode. I needed the LEDs to fill some holes of the housing that was left over from an unsuccessful project.
The two transistor RF amplifier increases the sensitivity and prevents also that Local Oscillator signals from the mixer are leaking to the antenna input. This would cause a lot of hum.
The mixer is a CMOS switch 74HC4066. Adjust the 5k potentiometer for the lowest AM detection of strong broadcast stations. This is done at the most critical frequency, find it by tuning the preselector across the bands. The mixer is followed by a transistor amplifier. The output can be connected to a sensitive microphone input of the soundcard of the PC.
Better is to add the second transistor amplifier. The output is connected to the less critical line input of the soundcard. A second output can be connected directly to the soundsystem of the PC (only the boxes with amplifier) when you do not want to use the PC. With a switch you can select the unique wideband or standard low-pass filtered audio (low-pass of approximately 2.5 kHz).

Tuning with an old mouse is a cheap and simple solution.
But it works so good that you can do that even with your toes!

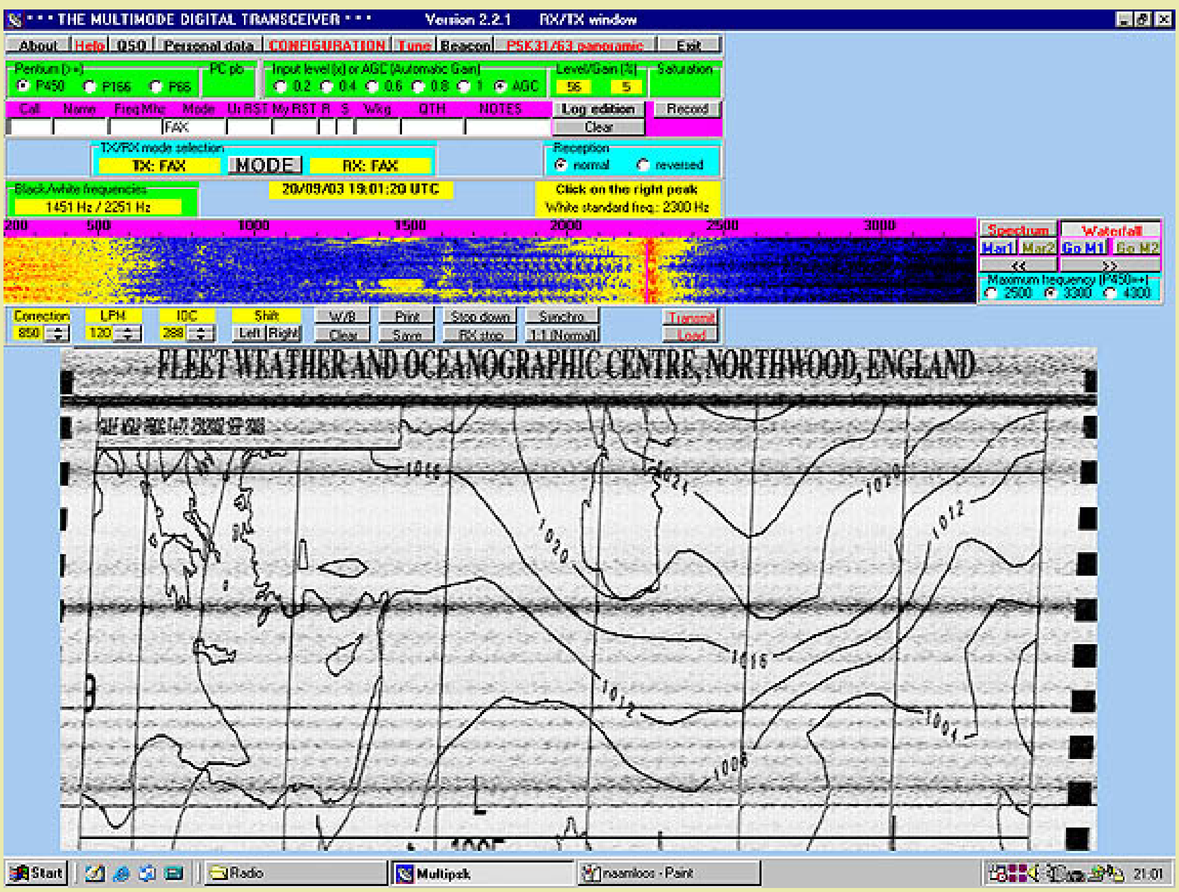
Tuning with the mouse works perfect!
Tuning of the DDS is done with a mouse instead of a rotating knob. There are 3 switches: Two for up/down frequency or faster/slower tuning speed and one for selection of frequency/tuning speed. I prefer this way of tuning above a rotating knob! The reception frequency goes slowly up or down when a button is pressed, depending on selected speed. At the lowest speed, it is very easy to tune it exactly to the frequency of an SSB station!

Results
The DDS PLL is used as VFO for this simple Direct Conversion receiver that is connected to the Soundcard of the PC. It is possible to decode various digital signals with free available PC programs, there are very nice DSP programs for filtering the wide band audio signal.
But most of the time this receiver is used in wide band audio mode: All signals from -8 to +8 kHz around the tuned frequency can be heard as background sound in the shack during home brewing or when using the computer. Performance is good, it is very funny to hear al the signals in such a wide band instead of only one in a narrow band as is the case when making a QSO. I never had a problem with the spurs and glitches.
Sensitivity and strong signal performance is good. Stability is perfect for digital modes.



Interior of the PC receiver.

DSP software and Decoding software for digital modes
The Multimode Digital Transceiver is a very complete program of F6CTE.
Although it takes some time to understand how the user interface works, it is a nice program with many decoding modes and DSP filters for audio reception.



The Multimode Digital Transceiver program F6CTE.

Here an example of a weather fax, Greece at the top left.
Enable the line or microphone input when receiving digital modes,
so that you can also hear the digital signal during tuning and reception.

BACK TO INDEX PA2OHH

80 METER CW TRANSCEIVER

(1998)

KLIK HIER VOOR DE NEDERLANDSE VERSIE

80 meter band CW transceiver with direct conversion receiver with sideband suppression.

Side band suppression with a direct conversion receiver
A superhet receiver with a crystal filter is a very good solution for single side band reception.
So why should we make a direct conversion receiver with side band suppression with the phase filter system? In the old days with electronic tubes, such a receiver was very complex due to the number of required tubes, big sizes and power supply. Nowadays it is easy, a few cheap op-amps and mixer IC's and that is it! I was curious about the performance of such a receiver and one of my intentions was to make it once in my life.
It is a nice receiver for home brewing. All processing is done on audio frequencies, making the construction not so critical. There is no complex or expensive crystal filter with its problems, no IF amplifier, no BFO oscillator, no mirror frequency that has to be suppressed. The VFO frequency is the same as the reception frequency. Therefore, no complex frequency counter with IF frequency offset correction is required, any simple counter is usable.
And a very big advantage is that you can use the same VFO for the CW transmitter without any extra mixers and filters!
When the design of a 74HC4066 mixer simplified the mixer problem considerably, it was time for me to start with the experimental construction of an 80 meter CW version of such a receiver.

A very happy end
And here already the result of the experiment so that you do not have to read the whole story to find that out.
It behaves just like a good superhet receiver without any spurious responses from mirror frequencies! Also the sensitivity is very good. Construction was easy with all good obtainable standard electronic components. Almost

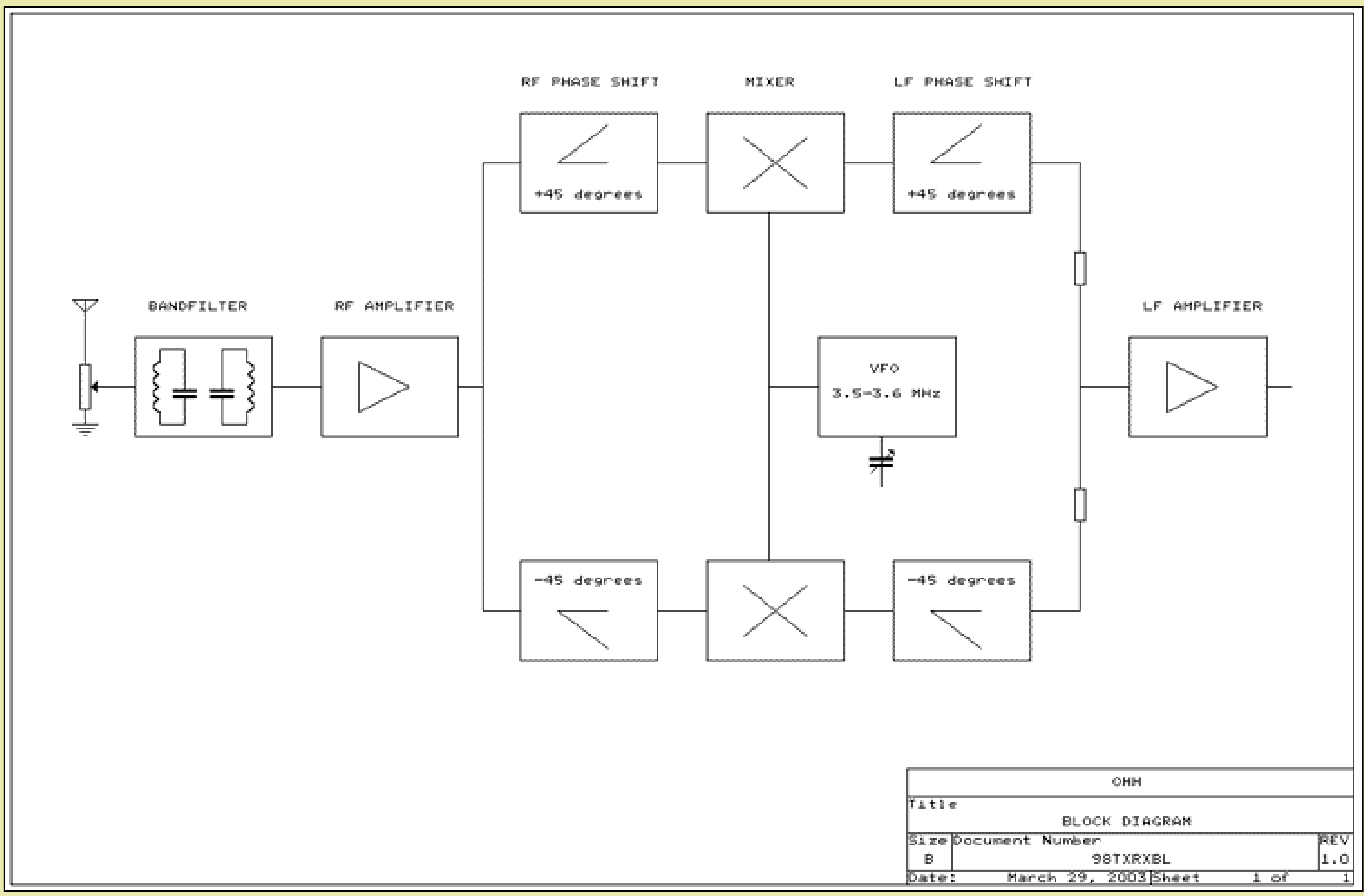
nothing is heard on the unwanted side band. Only some noisy signals from very strong commercial telex stations and some strong QRO amateurs, but very weak. It is really a pleasure to listen to this receiver. I am so enthousiast about the performance of the receiver that I also made a four band version. After a few years the mixer, side tone oscillator and audio preamplifiers have been modified to simplify and improve the design.

Side band suppression
A direct conversion receiver has less side band suppression than a superhet receiver with crystal filter. But do we really need the 50 to 60 dB suppression of a good commercial amateur receiver? To investigate that, I did an experiment on the 80 meter band.
An attenuator between antenna and receiver was set to a value that the atmospheric background noise just disappeared in the receiver noise, to eliminate its influence on the experiment. Then the 80 meter band was scanned with extra attenuators inserted and the results were noted down:

- 20 dB: All stations considerably attenuated. A very reasonable side band suppression.
- 30 dB: Some stations can be heard, weak to moderate. Would be a good side band suppression.
- 40 dB: Some strong stations can be heard but very weak. Really a very good side band suppression.
- 50 dB: Heard some very weak signals. An excellent side band suppression.

The conclusion is that the side band suppression should be better than 20 dB but between 30 to 40 dB is desirable. And the receiver has indeed 40 dB suppression, the first version had 37 dB a few years after the adjustment.

The phase method used here to suppress a side band

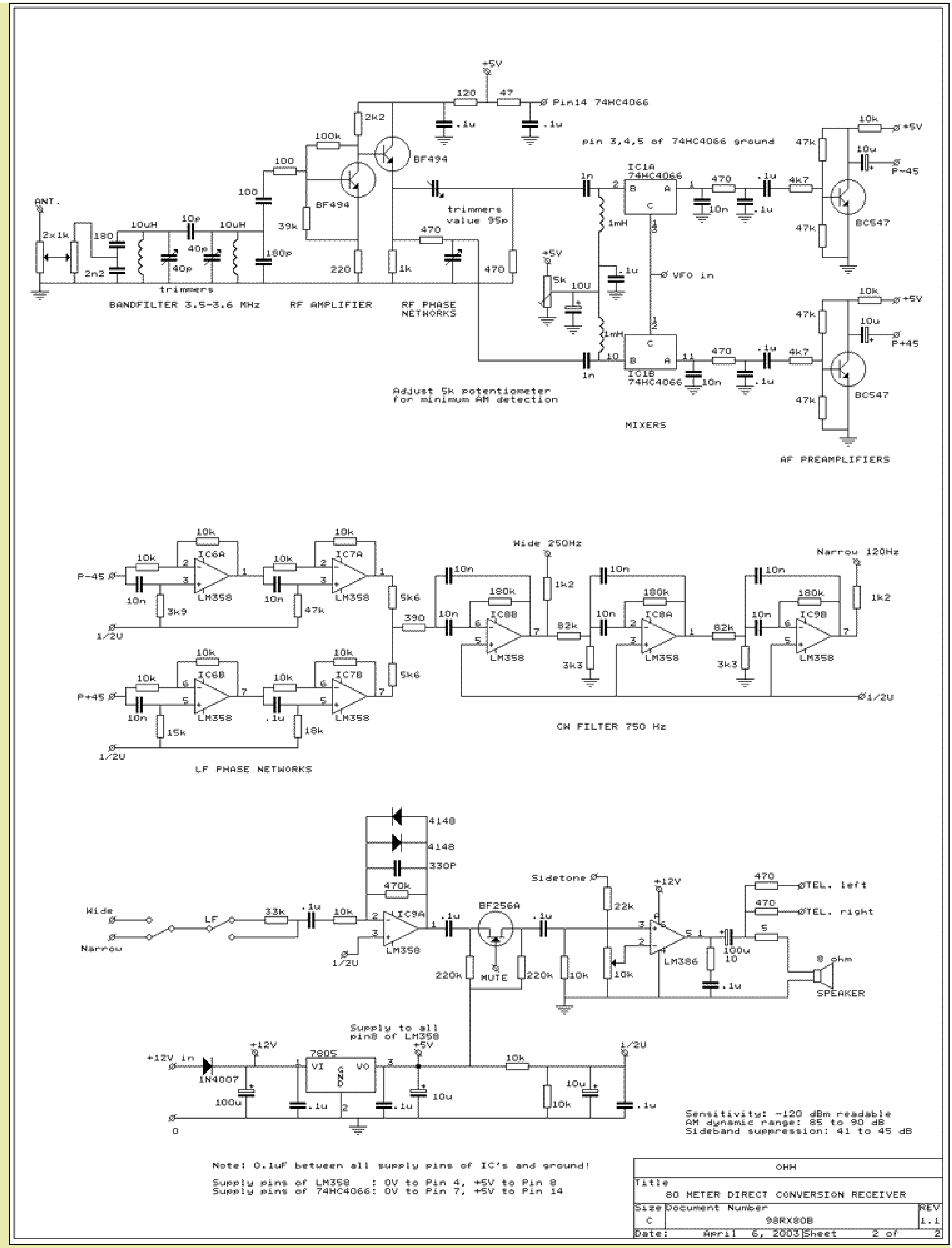


The phase method used here.
big diagram

The phase method of the 80 meter band receiver
The RF signal is split into two signals that are shifted 90 degrees out of phase (one plus 45 and one minus 45

degrees). Both are mixed to audio frequencies. The two audio signals are again shifted 90 degrees out of phase (again one plus 45 and one minus 45 degrees). When we add the two signals, one side band is in phase and added, the signals from the other side band are 180 degrees out of phase and substracted.
The RF phase shift circuits are simple RC combinations, the trimmers are adjusted for maximum suppression at 3550 kHz. The disadvantage of such a simple phase shift network is that the side band suppression is a little frequency dependent.
For the LF phase shift network I did not use the more common but complex polyphase network but a simpler version with operational amplifiers.
Both mixers are a CMOS switch. One 74HC4066 IC contains even four CMOS switches of which only two are used here! So a very simple and cheap solution for the mixer!

SCHEMATIC DIAGRAM OF THE DIRECT CONVERSION RECEIVER WITH SIDE BAND SUPPRESSION



Circuit diagram of the receiver

Circuit diagram of the receiver.
big diagram

The receiver in detail

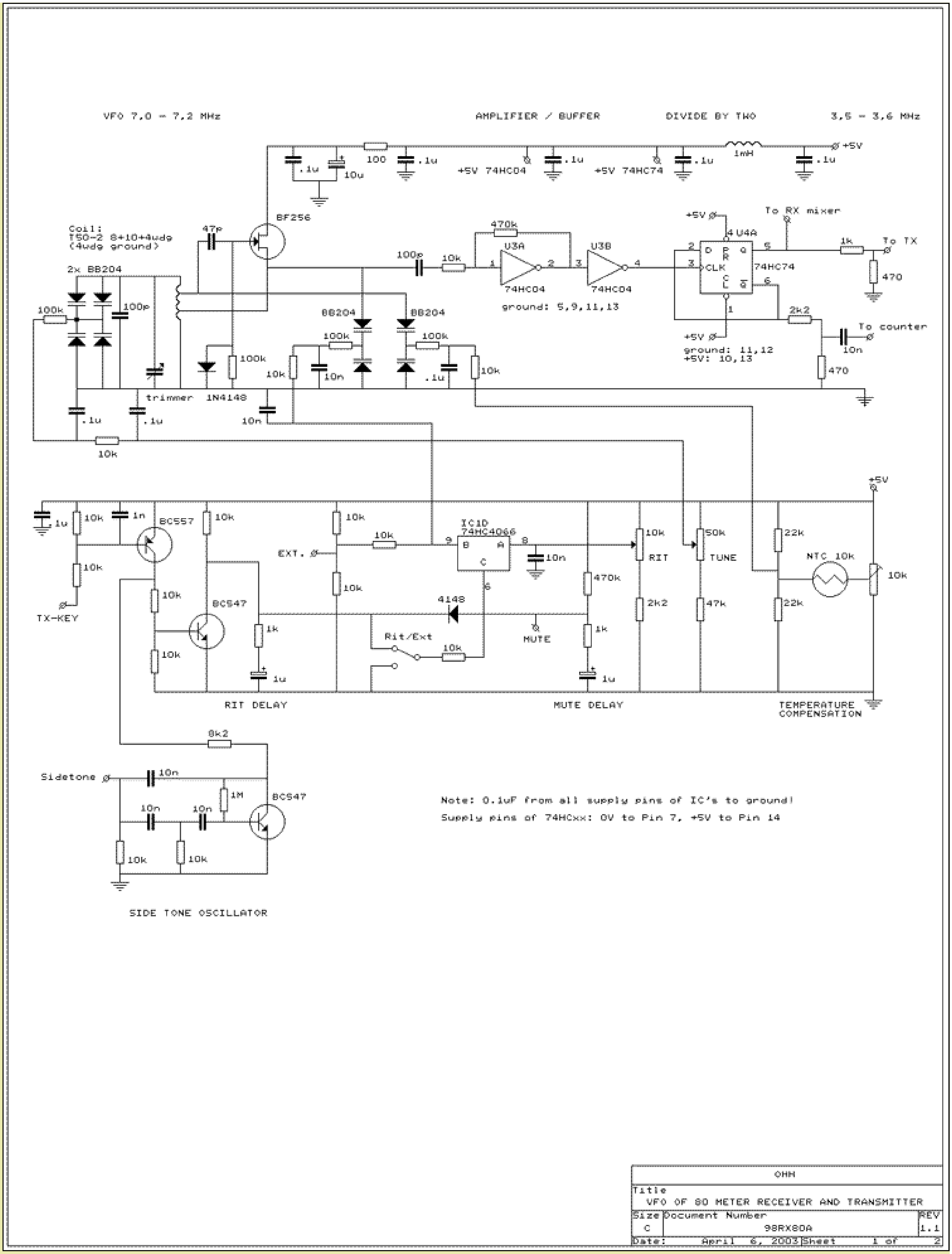
Preselector, RF preamplifier and RF phase shift networks
At the input, you will find the very useful RF attenuator. It is the main volume control. The preselector is a bandfilter tuned to 3550 kHz. The RF preamplifier has some gain, a high input impedance for the bandfilter and a low output impedance for the phase shift networks. After this preamplifier we have the RF phase shift filters. It are simple RC networks, both tuned with the trimmers for approximately 45 degrees phase shift. They also compensate for amplitude differences. For optimum settings for phase and amplitude, it is possible that one network is plus 55 degrees, the other minus 35 degrees as long as the difference is 90 degrees. Adjust it by ear, try different trimmer settings while adjusting the other at 3550 kHz while listening to a signal on the suppressed side band.
Usually, phase shifting is not done in the RF signal path but in the VFO. In that case, the VFO works at 4 times the reception frequency. The 90 degrees phase shift is obtained by dividers. The advantage of phase shift in the RF part instead of in the VFO circuit is that the VFO can work at the 4 times lower reception frequency and the RF phase shift network can also be used to correct for amplitude inaccuracies.

Mixers, LF preamplifiers and LF phase shift networks
The plus and minus 45 degrees phase shifted signals are mixed to LF frequencies by two mixers. These mixers are CMOS switches of a 74HC4066, very cheap and performance is good. Adjust the 5k potentiometer for minimum audio detection of strong broadcast stations.
To obtain the side band suppression, we also need phase shift networks in the LF part. The shifts have to be 45 degrees over the whole LF spectrum we want to receive. The networks in this receiver do their work with acceptable accuracy from 150 Hz to 5 kHz. However, for this CW transceiver only frequencies between 400 and 1000 Hz are important. I did use components with an accuracy of 5 percent with good results. The phase shift networks are a circuit with two op-amps and a few resistors and capacitors instead of the better but more complex polyphase networks.

CW filter and audio circuits
Both signals from the LF phase shift networks are added via 5k6 ohm resistors. Here the summation and substraction of the wanted and unwanted side bands happens. The wanted side band components are in phase on this point and are added, the unwanted side band are 180 degrees out of phase and substracted.
The audio CW filter has to bandwidths, a wide filter and a narrow filter. The wide filter is more pleasant and less tiring when listening for long periods, the narrow filter is very good when there is interference or for digital mode's like Feld Hell.
LF volume control is done by a switch as there was no place for a potentiometer. The switch lowers the gain of the next LM358 LF amplifier. The advantage is that not only the audio signal is decreased but also the noise of the LF amplifier. The diodes are limiting the peaks of the LF signal to 0.7 volt to prevent overloading of the BF256A mute switch. Take an =A= type for the BF256 as it has the lowest cut off voltage.
The LM386 is the final LF amplifier that has sufficient output power for a loudspeaker.

Modifications for SSB reception
The modifications are simple:
1. Two capacitors of 0.1 uF after the 470 ohm resistors at the output of the mixers IC1a and IC1b have to be replaced by 33 nF.
2. After the junction of the 5k6 ohm resistors at the output of the LF phase shift filters, the LF part is replaced by that described on the page of the shortwave receiver. Check the correct polarity connections of the elco with a voltmeter. If the LF gain is too high, increase both 5k6 resistors and that is it!
For SSB reception, Automatic Volume Control as applied in the LF circuit of the shortwave receiver is a very pleasant feature.

SCHEMATIC DIAGRAM OF THE VFO (PART OF THE RECEIVER)



Circuit diagram of the VFO

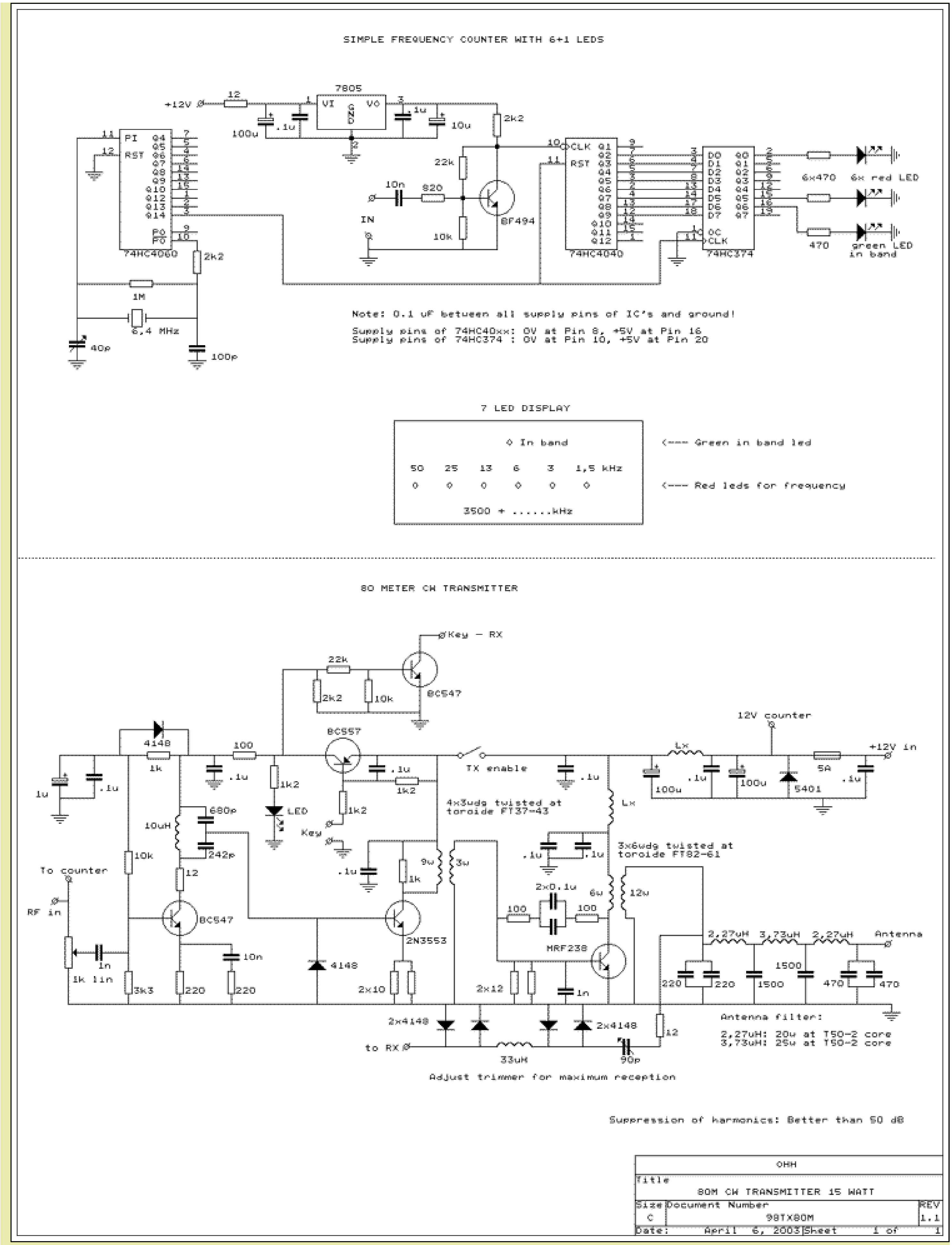
big diagram

The VFO and RIT

VFO
Did I just mention that it is an advantage that the VFO frequency is the same as the reception frequency? Indeed, but as this VFO is also used for the transmitter, it should not oscillate on the working frequency. This will cause frequency instability during transmission. That is why the VFO frequency is twice the working frequency: 7000 - 7200 kHz and is divided by two. It has to be screened!
There is also a temperature compensation circuit with the NTC. It is adjusted with the 10 k potentiometer while tuned on center frequency. I did that by measuring the frequency in the evening when the room temperature was 21 C and in the morning at 15 C. The frequency drift was improved with a factor 3 by this circuit.

RIT
The RIT is activated by a CMOS switch of the 74HC4066 IC that also contains the two for the mixers. The RIT on/off switch enables you to determine the zero position of the RIT potentiometer. At zero position, there should be no frequency change when switching the RIT on and off. I also made an input for an external control signal (for example frequency shift for telex or frequency stabilisation purposes), but I never used it.

SCHEMATIC DIAGRAM OF THE TRANSMITTER



Circuit diagram of the transmitter

big diagram

The transmitter explained

1st driver stage
With the 1k potentiometer, the output power is adjustable between 0 and 10 watt. After this potentiometer, the signal is amplified by a BC547 transistor. The output circuit (10 uH coil and capacitors) is resonant at 3550 kHz. Adjust the 242 pF capacitor for resonance at that frequency (maximum output power). It is not critical, it has a wide peak. This driver is switched by the morse key via the BC557 transistor. The diode and 1 uF capacitor are added for a correct shape of the CW signal.

2nd driver stage
The second driver is a 2N3553 transistor. The 1k resistor damps possible oscillations. The 2x10 ohm emitter resistors are a kind of limiter to prevent overdrive of the stage.

Final RF amplifier
Of course you should not use such an expensive VHF transistor but for example a 2SC1969. I had a MRF238 transistor unused in the junkbox.
The 2x 12 ohm at the base create a low input impedance, important for a good stability. The 1 nF capacitor has a low impedance for higher frequencies, it prevents HF and VHF oscillations. And finally, the 2x 100 ohm resistors with the 2x 0.1 uF capacitors are a negative feedback circuit that prevent oscillations at frequencies below 1 MHz.
Due to the 6 element antenna filter, the suppression of the 2nd harmonic is 53 dB and that of the higher harmonics are more than 60 dB.

Antenna switch
The 90 pF trimmer is adjusted for resonance at 3550 kHz with the 33 uH inductance. Both anti-parallel diode pairs are limiting the RF signal from the transmitter to the receiver. The first diode pair is connected to a point with a very high impedance, so the current via the diodes at that point is low. The resistor of 12 ohm is a kind of fuse. Smoking if something goes wrong. The second diode pair is not necessarey. It is just there as an extra protection if something else in the circuit fails.

Simple frequency counter
The simple frequency counter is described somewhere else at this website. Six leds are used to display the frequency. One green led at Q7 is the in-band led (frequency between 3500 and 3600 kHz).
Add the value of the leds and you know the frequency. For example: Leds 3 kHz, 6 kHz and 50 kHz are on for 3559 kHz. If you tune a little higher in frequency, the 1.5 kHz led starts burning and you are at 3560.5 kHz, just above the QRP calling frequency. Turn a little backwards and you are exactly on 3560 kHz. A very simple circuit and it absolutely not difficult to read out the frequency.

Notes
Built via the ugly method (dead bug method). Parts are soldered at one side of he double sided unetched print.
The VFO has to be placed in a screened enclosure. The frequency counter is also screened with chicken wire.... The advantage is that you can make some modification or adjustments through the holes of the chicken wire.
Inductances are commercially available types looking like big resistors. Lx are wired 6 hole cores.
Do not use a 74HCT type but a 74HC type for the IC's!
I made a seperate transmitter and receiver, both in it's own enclosure. They are connected with plugs and cables. The RF signal from the VFO to the transmitter goes via coaxcable with BNC plugs. The other wiring is with screened audio cable.

Performance
Sensitivity: -120 dBm (0.2 uV) signals are readable
AM dynamic range: 85 to 90 dB (good)

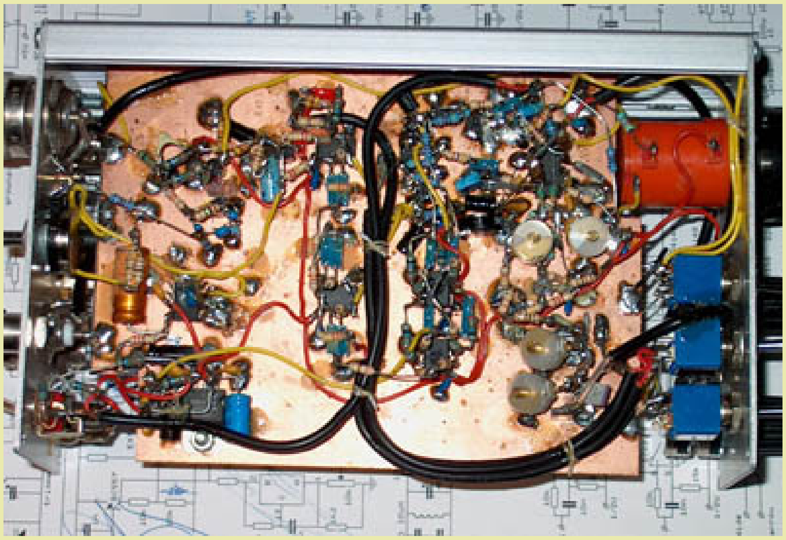
Side band suppression:
3500 kHz: 42 dB

3550 kHz: 45 dB
3600 kHz: 41 dB
Note: a few years after the adjustment, the first version had more than 37 dB suppression.

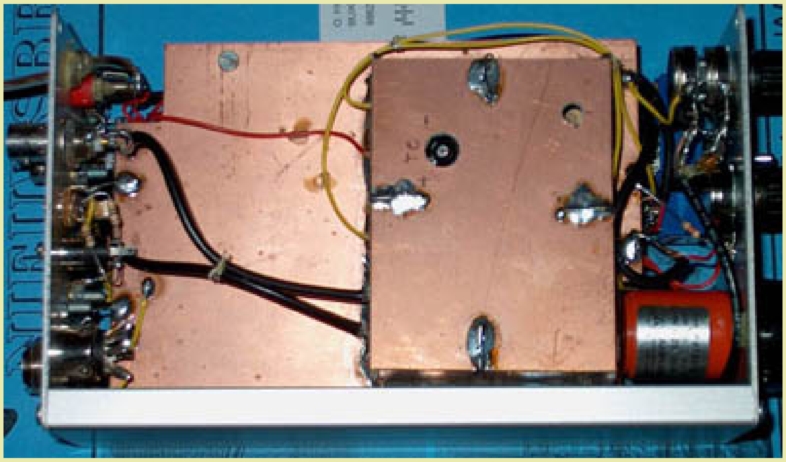
Transmit power: max. 15 W at 14 V
Suppression of harmonics: Better than 50 dB

As said before, I like this receiver, side band suppression is good and I really do not have a need for a commercial superhet transceiver.

PHOTOGRAPHS

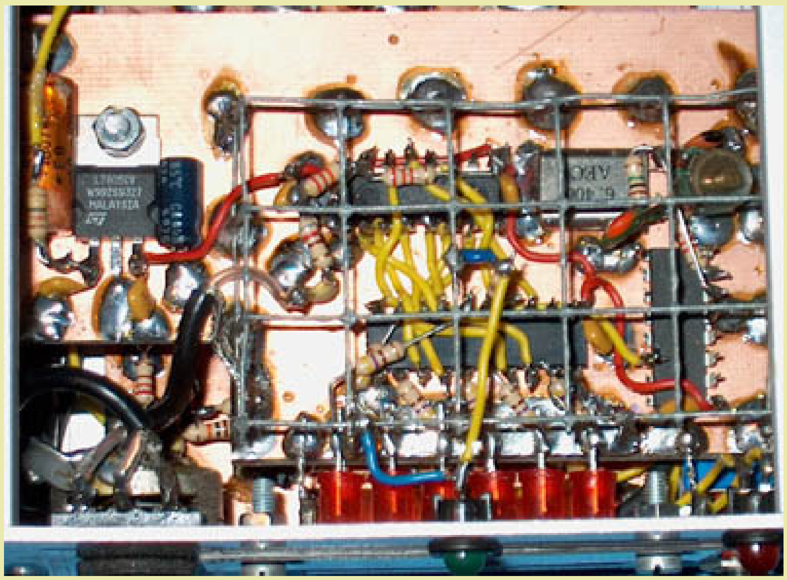


Direct conversion receiver with sideband suppression.



VFO of Direct conversion receiver in a screened enclosure!

Transmitter



The very simple but efficient frequency counter with 7 leds, only 3 IC's and it's own 5 volt stabilizer. Screened with chicken wire...

[BACK TO INDEX PA2OHH]

Tune Around!
SEARCH

CQ-Calling All Hams!
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Antenna Design
Antenna Safety!
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About Batteries
Code Practice
Computer Help
Electronics
FCC Information
Ham Hints
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The End Fed Antenna: Killer or Compromise?

by John Reisenauer, Jr. KL7JR

This article is of a "homebrew" nature which includes a "review" of my experience using a 10-40m HEARC (Honolulu Emergency ARC) end fed matchbox antenna installed in a unique way from an RV park. I say unique because it was about the only way I could do it without everyone seeing it! The HEARC matchbox antennas are assembled by volunteer member hams and sold world-wide. You can buy the assembled antenna or their kit and put it together yourself (see pdf download below).

The dipole is probably the simplest antenna to make and install. I'm not a fan of dipoles even if they are efficient (I like the venerable G5RV and have used them for over 25 years). An end fed aerial is a dipole but terminated on an end making them very easy to install. You can mount them horizontal, vertical, sloping, as a half square or even an Inverted L. I must admit I never heard of end fed antennas until only a few years ago. It was time I got smart on them.

End feds are a single wire, full length half wave monoband or multi-band dipoles, operating without any radials or grounding. This simple aerial has been forgotten over the years in part I suppose due to the 9:1 balun which may be confusing to some hams. Hams claim end feds are; noisy, they cause interference and a good earth ground and an ATU is required. Well, I agree partially but not that they are noisy and an earth ground is required. Granted the ground is smart to have but sometimes on my portable trips that just isn't easy to do. I mean how do you get a ground on a glacier, or drive a ground rod when it's 40 below?

Today you can buy an end fed from MFJ, LNR, Saga, HEARC and many others advertising on the internet. I purchased a preassembled 10-40 meter end fed antenna ($49.00 shipping included to USA-2013 price) handling 100 w from HEARC while my friend Bob K5YB got their kit. Bob said it was a piece of cake to build. So there you go, build a monobander or a multi-band matchbox end fed aerial or be lazy like me and have someone do it for you! Here's what I got off the internet while searching for end fed antennas.

There are two main benefits in using an end fed half wave antenna over a coax fed half wave dipole. The main benefit is that the antenna feed impedance is around 2500 ohms and very little RF current flows into the RF earth or counterpoise. In many applications the coax feed to the antenna matching unit will act as an efficient counterpoise. If used as a vertical antenna then it doesn't need an extensive set of earth radials to be efficient. The second benefit is that the point of maximum radiation is half way along the antenna. If the antenna wire is suspended vertically from say a tree or pole then with the 20m version the point of maximum radiation is 5m above ground level usually well above local ground level without having to run earth radials. Again the point of maximum radiation is half way along the antenna wire giving some isolation from RF interference carried on the building's electrical power source.

Let's see what others are saying about end fed antennas:

N2CX says..Hams in general, and QRPers in particular, are always on a quest to find the "ultimate" antenna. Of course there is no single skywire that fills every ham's needs, but there is one type that belongs in the casual portable QRPer's bag-o-tricks. What I'm talking about is a classic historical aerial, the End-Fed Half-Wave Antenna (or EFHWA, pronounced "EFF-WAA"). It is extremely simple to build, erect and use. In spite of its simplicity the EFHWA has the benefit of giving repeatable, efficient and effective performance.

The total overall length of the EFHWA is an electrical half-wavelength, calculated from the formula L (Ft) = 468/F (MHz) where L is the overall wire length in feet and F is the desired operating frequency in Megahertz. This is the length of wire right from the tuner terminal to the insulator at the far end. The formula is approximate, taking into consideration the "end" effect which makes the antenna shorter than a half-wavelength in free space. Extreme accuracy isn't necessary, since even the simplest tuner will make up for inaccuracies of five percent or so. Additionally, a wire that is any multiple of a half-wavelength has the same impedance characteristics; for example, a wire cut for 40

meters will also be useful on 20, 15 and 10 meters with a suitable tuner. Mine works quite well on the WARC bands too!.

The EFHWA needs a ground connection, but it does not need to be very extensive. The ground or counterpoise connection simply acts to decouple the tuner and rig from the antenna system by providing a path for ground current to flow. A quarter-wavelength wire, which is half the antenna length, laid out along the ground or tucked out of the way is usually sufficient. Outdoors either the counterpoise or a short jumper connected to a large metallic structure such as an automobile or camper also works fairly well. When one end of the antenna is indoors, such as in a motel room, a heater radiator or air conditioner can be pressed into service. Try whatever ground you have to see if it works.

W8JI says...End-fed antennas are increasingly popular again, at least partly because of compact iron toroid cores. Small soft-iron cores allow compact, easy-to-build, low-power transformers and networks. The combination of lightweight compact matching systems, combined with the installation convince, visual appeal, and installation simplicity of NOT hanging a heavy coaxial feeder from a long span of thin antenna wire, has rekindled interest in end-fed half-wave antennas.

Unfortunately end-fed antennas have also come back with a little misconception. One commonly repeated myth or "theory" is that half-wave antennas, being resonant, do not require acounterpoise. Lack of a proper counterpoise does not mean the antenna will be worthless and not make contacts, it simply means something else replaces the missing counterpoise area. The feed line, as well as everything connected to and surrounding the feed line, become part of the radiating system. This creates three potential problems:

1.) The feed line, mast, and things around the feed line connect into the receiver. This brings noise into the receiver.

2.) The feed line, mast, and things around the feed line become part of the radiator. This brings voltage (electric fields) and current (magnetic fields) directly into the shack.

3.) The feed line and grounding affects SWR and tuning.

Transmitter power levels, feed line length and routing, and the susceptibility of equipment to RF problems greatly influence things we most likely notice. This is why some people (usually with QRP power levels) swear by end-fed half-waves, while others (usually with higher power) avoid end-fed antennas. The reason for that is simple, end-fed half waves have common mode feed line current problems affecting their performance, and these common mode currents cause inconsistency in user satisfaction. End-fed half wave antennas are best for temporary antennas using low power and batteries, far from power mains and noise sources. They are more prone for problems near noise sources or consumer gear, and can easily exceed FCC RF exposure limits with surprising low power levels.

KL7JR 10-40m HEARC matchbox antenna ready to go up.

In nearly all cases, if we notice it or not, an inadequate counterpoise hurts antenna pattern and efficiency. This is why high power stations often have more efficient, more ideal, antenna systems. Higher power very often excludes use of power wasting systems, because the wasted power often creates significant local problems. If 5 percent of 10 watts is exciting the desk with RF, it isn't any big deal. If 5 percent of 1500 watts excites the desk with RF, the result can be hazardous.

See attached pdf files for more info on the end fed matchbox antennas.
4Z1PF END FED PDF (Build it yourself instructions)
HEARC END FED PDF (Build or buy it already built)

What do I have to say about my end fed? I'll let my KL7JR/K7ICE log talk (Sept. 2- Nov. 2, 2013. States excluded except Alaska but I worked 45!).

ALASKA 10, 15 & 20 ALBERTA 10, 15 & 20 ALAND ISLAND 10 ARUBA 10, 15 & 20 AZORES 10, 15 AUSTRIA 17, 20 ARGENTINA 10, 15 BARBADOS 17 BELGIUM 15, 20 BONAIRE 10, 20 BOSNIA-HERTZ. 15, 20 BRAZIL 10, 15 & 20 BULGARIA 17 BRITISH COLUMBIA 15, 20 CAPE VERDE 15 CANARY ISL. 20 CHILE 10 CUBA 20 COLOMBIA 10, 15 CURACAO 15, 20 CORSICA 10 CZECH REP. 15, 20 CROATIA 10, 15 & 20 COSTA RICA 10, 20 ENGLAND 15, 17 ESTONIA 10, 15 ECUADOR 15 FRANCE 10, 12, 15, 17 & 20 FINLAND 15 GRENADA 10 GUATEMALA 10, 12 GERMANY 10, 12, 15, 20 HAWAII 10 HUNGARY 10, 15 ISLE OF MAN 17 ITALY 10, 12, 15, 17, 20 IRELAND 20 ICELAND 15 LUXEMBOURG 20 LITHUANIA 12 MEXICO 10, 15 & 20 MANITOBA 15, 20 MOROCCO 20 MADIERA ISLAND 12, 15 NEW BRUNSWICK 20 NOVA SCOTIA 17, 20 ONTARIO 20 POLAND 10, 15 & 20 PUERTO RICO 10, 20 PORTUGAL 10, 20 PERU 15 QUEBEC 15 RUSSIA 15 SASKATCHEWAN 10, 15 & 20 SABA 10 SCOTLAND 15 ST. LUCIA 10 SLOVAK REP 10 SERBIA 15, 20 SWITZERLAND 15, 20 SPAIN 10, 12, 15, 17& 20 SLOVENIA 10, 12, 15, 17 & 20 TRINIDAD & TOBAGGO 15 TURKS & CAICOS 15 UKRAINE 15 URUGUAY 10 US VIRGIN ISLANDS 10 VENEZUELA 17 WALES 10 YUKON 10

KL7JR HEARC 10-40m End Fed Installation on roof of RV in Fort Mill, SC.

What antenna??? As you can see, the matchbox aerial is quite stealthy. I doubt any one knows what I'm doing in the RV campground! The bottom of the matchbox coax connection is about 4 feet above the roof and then vertical section goes about 10 feet as a sloper then levels off and zig-zags horizontally through the tree branches 5-10 feet above the roof. Antenna comes with 30 feet of wire and by experimenting; I added about 15 feet to get a better match on 40m. Earlier on I mentioned I didn't much care for dipoles, and what I've experienced with this wire aerial only about 20 feet high has me totally dumbfounded especially because I have no ground radial system nor is my rig even grounded! Later on I will try this aerial as a vertical, but for now I'm having too much fun! You decide if it's killer or compromise. I already have and will order another matchbox soon!

73 de Yukon John in South Carolina

UPDATE - Operating from Dominican Republic 07-2014

HI3/KL7JR 2014 Log QTH: Cabarete, Dom Rep
Download pdf file of log

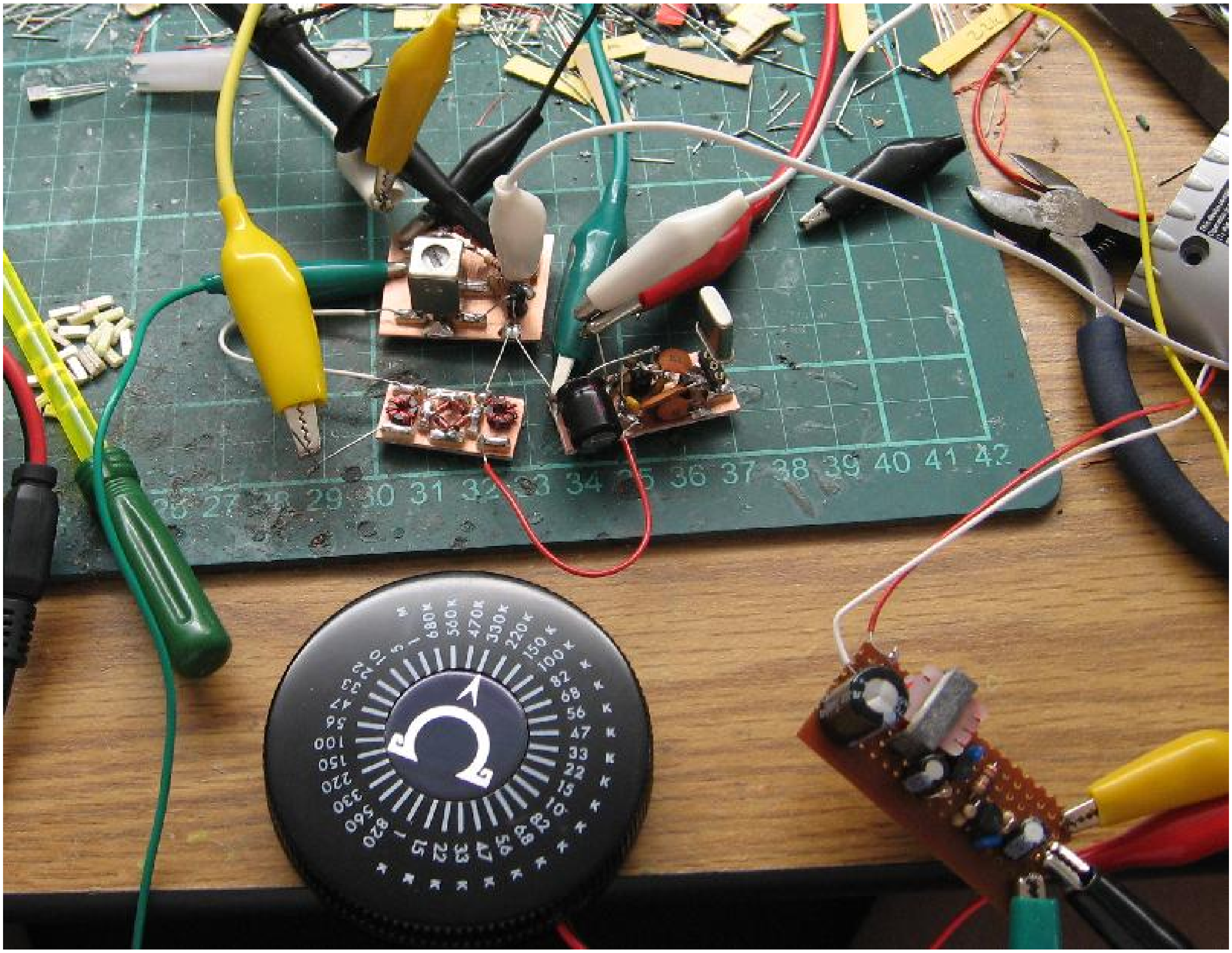
{Footnote 12-12-2013}

The 45 ft long End Fed is up about 20 feet and mostly horizontal. The Inverted L is up 40 feet and about 55 feet long with 3 long ground radials.
On 10-20m the End Fed consistently out performs the Inverted L by 2 to 4 "S" units.
The Inverted L will stay up for 40 and 80m use.

A Working Receiver

2007-02-17

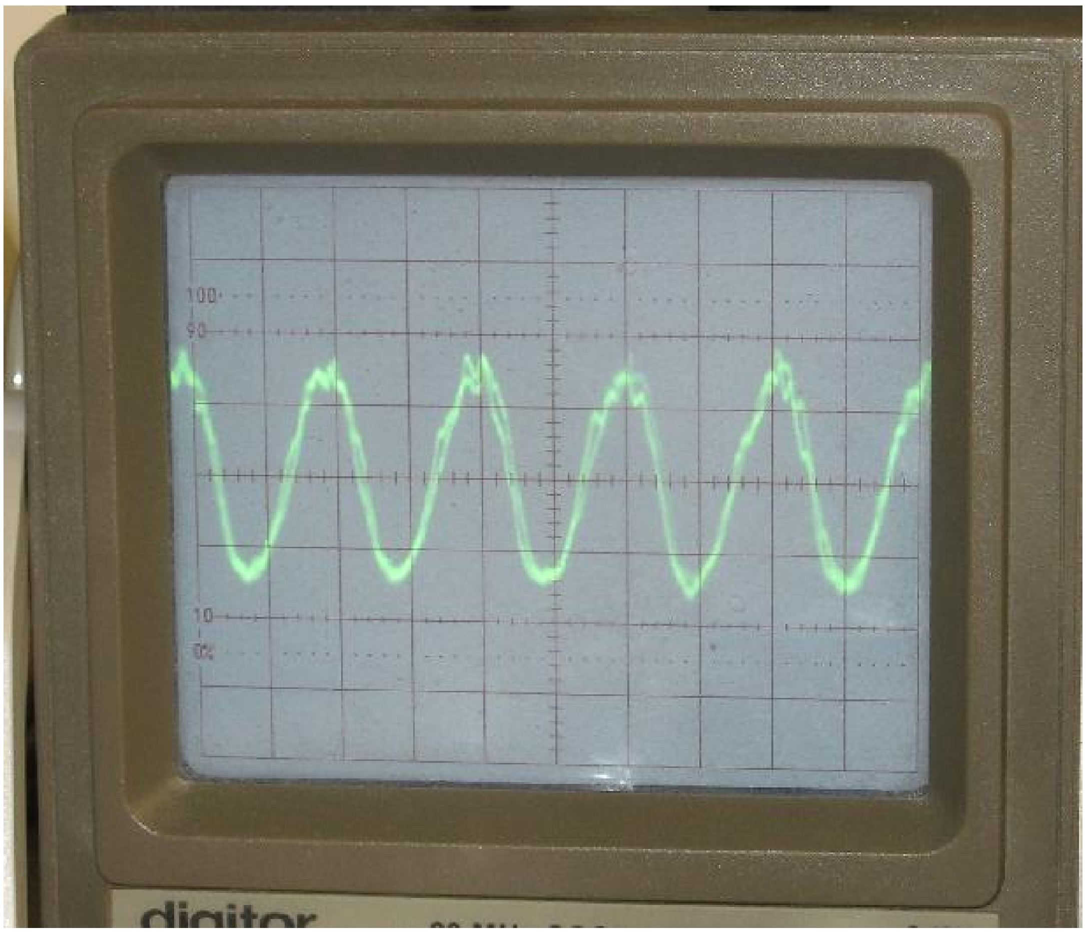
I completed a basically working AM receiver using the IF building-block from last week:



Note the lash-up with a 3.2768 MHz crystal oscillator, and the a two transistor veroboard AF amplifier I often use while prototyping. The resistance wheel is just acting as an attenuator for the AF signal path.

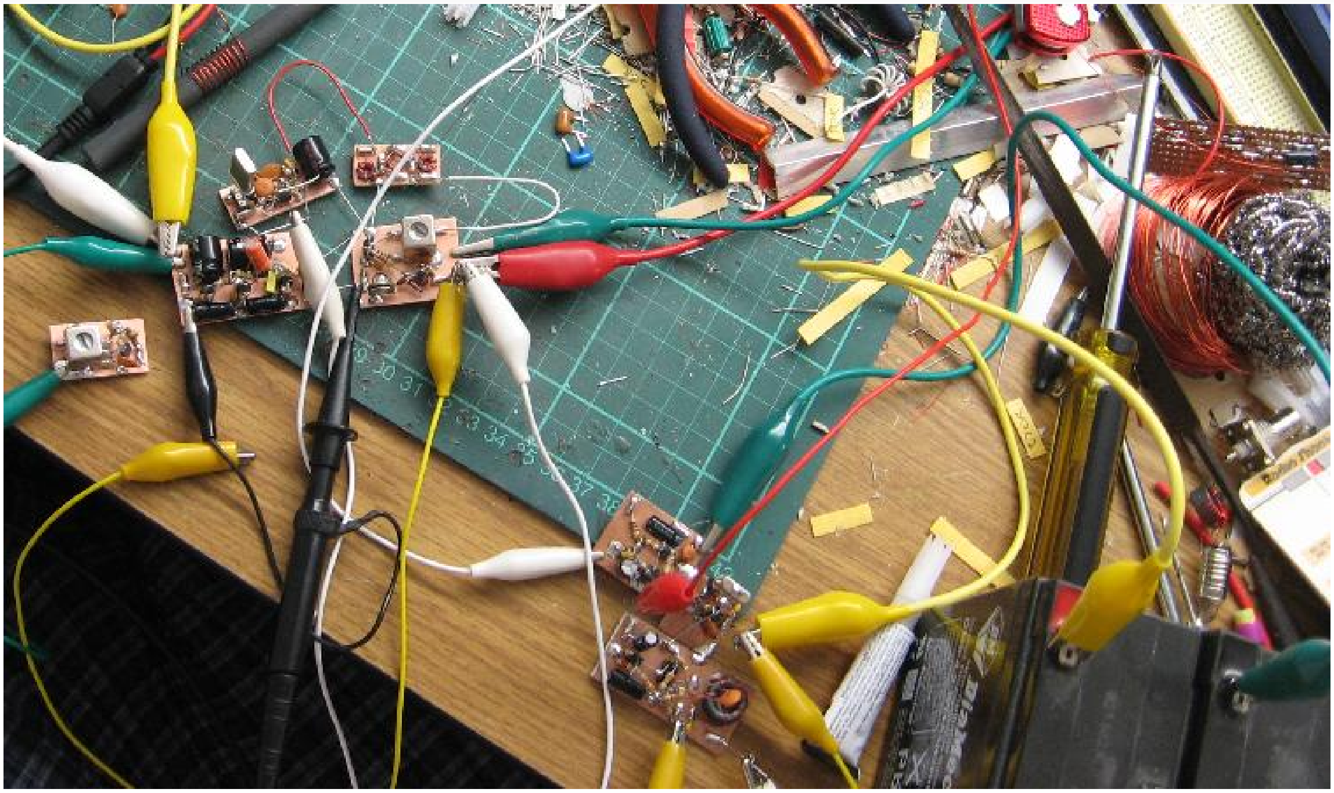
Some FT23-43 ferrite toroids arrived during the week from Kits and Parts. These tiny things allowed me to make an pretty small mixer without using excessively thin and difficult to manage wire, as I usually would when using ferrite beads at this frequency to get sufficient reactance (i.e. more than two or three turns through the bead means the wire must be very thin).

The receiver produced a noisy, but quite usable signal from about 10uV of RF at 3.68 MHz:



Finally I could use the AM transmitter to produce a test signal for the receiver. For this test, the TX was powered from a pair of 6 V gel-cells. The receiver was powered from my bench PSU. My VR-500 supplied the audio signal for the AM modulator, tuned to an FM radio station.

A dedicated AF amplifier was built for the receiver. I actually made it too sensitive, using a design I would normally use for direct conversion receivers. The output of the MK484 is high enough to make such extreme AF gain unnecessary. Removing the emitter bypass on the first stage offered acceptable gain, but a simpler amplifier with only two transistors would be sufficient. I also made the output class-A, with a 2N3904 standing quite a few mA - I may rebuild this module to something less of a hack, more efficient, and better suited to the mV output level of the MK484.



Note the small board with an IF can on it, this is a 455-ish kHz BFO oscillator for resolving CW/SSB. This doesn't work as well as a proper product detector, the injection level needs to be adjusted with varying signal strength, but the AGC makes a set level usable over a fair range. Higher injection levels de-sense the IF by activating its AGC. There is little way around this as the AM detector is buried inside the MK484 where you can't access it for BFO injection, and is simply the price you pay for such a simple IF circuit. That said, the BFO works fine, I was able to receive the ARNSW morse beacon on 3.699 MHz using this receiver and the BFO. Some success was obtained from injecting the BFO into the mixer LO port, requiring somewhat less injection level adjustment. I would like to avoid a front-panel BFO level adjustment, but a simple switched pot would be a practical solution if you don't mind the extra control.

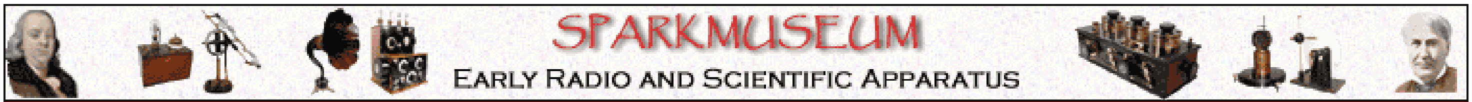
Some VHF break-through interference was observed with the IF stage during testing. Vega FM at 95.3 MHz would be heard in the noise, extremely distorted. I assume the fairly long input lead from the MK484 to the IF can pad is picking this up, nothing else in the circuit changes the effect when touched. Shielding will correct this, but if I build this kind of IF circuit again I'll be more careful with the layout of this rather high impedance point.

As currently lashed-up the front-end allows anything into the mixer. This means it can harmonically resolve signals, for example, Radio Australia's monster signal on 6.020 MHz made it impossible to listen for ARNSW's morse beacon 3.699 MHz until after the shortwave station moved to another allocation for the day. While their respective IF frequencies where 100 kHz apart, the receiver selectivity was not sufficient to handle the enormous shortwave signal, some front-end filtering will take care of this. A ceramic filter in the IF path would improve the selectivity, or a Q-booster on the IF resonator.

By tuning around with the IF can, the receiver as-is makes a usable shortwave receiver. The AF amplifier can produce ear-splitting audio into headphones, and pretty room-filling audio using a matching transformer into a small speaker. You just slot in different crystals and tune around with the IF can, but doing so will eventually take its toll on the IF slug and its plastic threads. It would be a simple matter to replace the crystal LO with a VFO and tune that way. In fact, once I improve the selectivity I may build a copy to dedicate to SWL. The very trivial nature of the circuit would make it an excellent project for novices or foundation calls (or whatever we call newer hams now days).

2 comments.

Parent article: "2007 80m Homebrew Challenge".



Radio Detectors


Branly Coherer
(Replica)

A *detector* is a device that converts a high frequency radio signal into a low frequency audio signal that can be heard through headphones or amplified and played through a loudspeaker. The very first detectors were used only to detect the presence of an electromagnetic pulse, since modulation hadn't been developed, and communication was accomplished by transmitting electromagnetic pulses in Morse code. One such detector was the Coherer, used by Marconi in its earliest receivers.

By the early 1900's the coherer had been replaced by various crystal technologies capable of detecting high frequency AM radio signals By the mid-teens, vacuum tube detectors such as the DeForest Audion were also popular. Below are several of the detectors in my collection:

Marconi Magnetic Detectors c. 1904

Known as the "Maggie", it was the standard detector used on ships from 1902 to 1914. Click here for more information.


Cover in place


Cover removed


This is another Maggie I own, which has no cover.

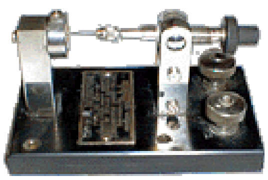

Epochet Ball Coherer
4th qtr 19th century
(German)

The Ball coherer consists of a glass tube enclosing several steel balls. It operates on the "dirty contact" principle discovered by Hughes. An adjustment at the top of the tube provides a way to vary the pressure on the stack, thereby changing the electrical characteristics of the detector.

**Lowenstein SE 183-A
Triple Detector
1917**

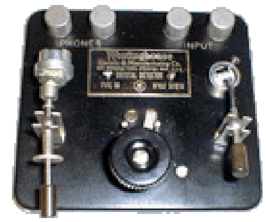
**Unknown Early Crystal Detector
c. 1915**

**Adams Morgan
Crystal Detector
Approx. 1916**



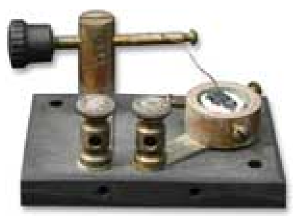
**Lowenstein SE 184-A
Galena Detector
1918**

**Adams Morgan CR 1235
Si/An Detector
1919**



**Westinghouse DB Dual
Detector
1921**

**Kilborne & Clark
Galena Detector
Seattle, WA**

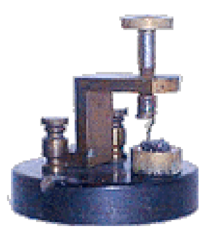


**Krows Electric Co.
Galena Detector
Seattle, WA**

**Krows Electric Co.
Galena Detector
Seattle, WA**

A.W. Bowman Galena Detector

Sold in 1917 by Sears, Roebuck & Co. as the "Universal Detector Stand."

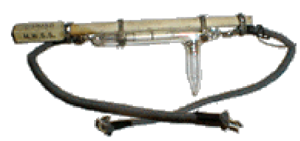


Unmarked Early Crystal Detector

**Electro Galena Detector
1914**

Wireless Specialty Perikon Detector

Wireless Specialty Pyron Detector

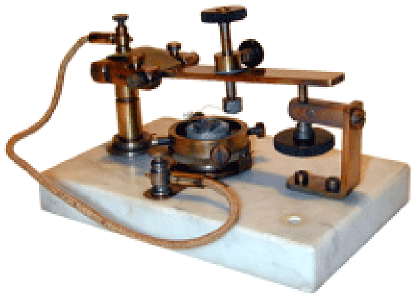


**Marconi Coherer
1895-1905**

One of the first devices used by Marconi to detect RF signals. Click here for more information

DeForest Tubular Audion
1916
Click here for more informaton

DeForest Spherical Audion
c. 1914



Early Unidentified Crystal Detector

Fleming Valve
(British)
1910
The Fleming valve is considered to be the grandfather of all thermionic vacuum tubes. Click here for more information.

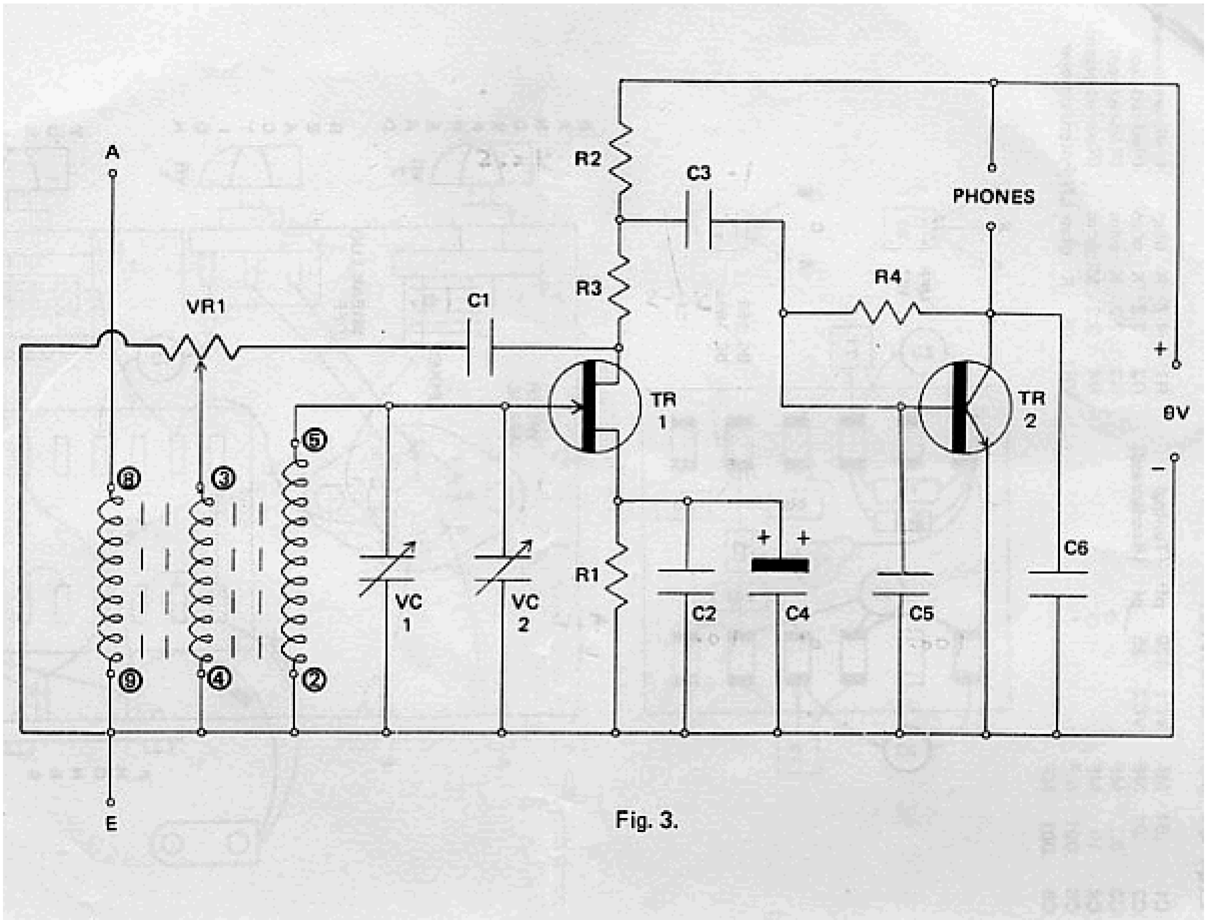
Thanks to Craig Smith for the following background on the "SE" designation: The Bureau of Steam Engineering came into being July 1,1910--commanded by Rear Admiral Hutch I. Cone. Among their other (more steam related activities) they were responsible for "providing radio stations and equipment and for maintaining them." Prior to 1910 the Navy had used a mostly civilian Wireless Board to advise in procurement of civilian radio apparatus. The Bureau of .S.E. and the Naval Research Lab shared design responsibility and to some extent manufacture of some radio items. Those items designed by the Bureau carried the "SE" prefix. Other items, like the CR1235 detector were designed by outside firms and adopted by the Navy. The "CR" prefix in this case stands for Wireless Specialty Co. Adams-Morgan must have built them under license.

The HAC Model "T" Twin Transistor Receiver

The HAC transistor receiver kit was produced by HAC Short Wave Products of East Grinstead, Sussex. It was a popular choice for those interested in both short wave listening as a pastime and also the construction of their own radio set.

Although simple in design, the HAC provided excellent reception of strong and medium strength signals, and with careful adjustment could also resolve quite weak stations on the short wave bands.

Below are images of the original instruction booklet which was kindly sent to MDS975 by J Haskell.



The HAC circuit diagram

CONSTRUCTION

1. Mount the coil holder on the underside of the chassis using two bolts and nuts. Note the position of the wider space between pins 1 and 9. See Fig. 2.

2. Mount the two socket strips for headphones and aerial/earth on the outside of the chassis with the prongs protruding inwards using two bolts and nuts for each strip. Punch out the holes in the dial card and mount it with adhesive to the front panel. Bend the two phones tags up to clear T2.

3. Mount the tuning capacitor (using the two short counter-sunk screws) the 5 K ohm potentiometer and the bandspread capacitor in the positions indicated in Fig. 2. The two short screws will pass through the dial card. The bottom lug on the tuning capacitor should be flattened and the shake-proof washer on the potentiometer should be on the inside of chassis.

4. Hold the soldering iron to all tags on the tag board in turn and apply solder to "tin" them in readiness to receive the components. Mount the single soldering tag in the centre of the tag board using a bolt with a nut on the underside. This nut will also serve to space the board away from the chassis.

5. Solder the wire links on the tag board and mount the various resistors and capacitors in the positions shown in Fig. 1 The wire leads on these components should be shortened to make neat wiring, and "tinned" first to assist soldering. Note position of black band on C4.

6. Examine the transistor connections as shown in Fig. 1 and spread the outer leads carefully to span the tags on the tag board. Note that they have a 'flat' on one side. The transistors should now be soldered to their relevant tags, taking great care that they are not overheated by the soldering iron. Just a quick touch with the iron should be sufficient. These should be mounted vertically with their flat sides outwards from the centre of the tag board.

7. Secure the tag board to the chassis through the hole provided with a nut on the top of the chassis. See that it is "square" with the chassis. Connect C1, run wires from the tag board and connect the red and black leads of the battery "snap" connector as shown in Fig. 2. The bandspread capacitor should have a wire connected from one of its prongs on the "fixed" vanes at the back to pin No. 5 of the coil holder.

8. Connect the aerial socket to pin No. 8 of the coil holder. Connect pins 2, 4 and 9 to the centre spigot of the coil holder and take a wire from there to the earth socket. Run a wire from the earth socket and loop it under the adjacent nut which secures the aerial/earth socket strip to the chassis. Tighten the nut.

9. Cut the spindle of the potentiometer to the same length as the other two controls and fix the three operating knobs.

10. Unscrew the brass thread on the coil so that approximately ¼" protrudes from the coil former and insert the coil in its holder. Plug the headphones into their sockets. These should be of 2,000 ohm resistance for best results. Connect a battery type PP3 or similar.

11. Connect an aerial of about 30' to the aerial socket. An earth is not essential for coil Nos. 4 and 5 but helps considerably with coil No. 3. Only coil No. 4 is normally supplied with the kit.

12. Turn the reaction control potentiometer fully anti-clockwise and then turn it slowly in a clockwise direction until the set is heard to go into oscillation. For ordinary 'phone signals the receiver should be operated with the reaction control held just below the point of oscillation. It will be noted that this setting will vary according to the position of the tuning condenser and both hands will be needed to search for stations. For SSB and CW signals, the reaction control should be set so that the receiver is oscillating. The use of the reaction control needs some practise.

Figure 3 shows a schematic diagram of the receiver circuit.

Constructional details

LIST OF COMPONENTS:–

C1	.01	MF	VC1	170	pf	(Tuning)	R1	4.7	K	ohm	(yellow-mauve
C2	.01	MF	VC2	35	pf	(Bandspread)	R2	2.2	K	ohm	(Red-red-red)
C3	0.1	MF					R3	2.2	K	ohm	(Red-red-red)
C4	10	MF					R4	2.2	M	ohm	(Red-red-green
C5	.001	MF					VR1	5	K	ohm	LN Potentiometer
C6	.001	MF									

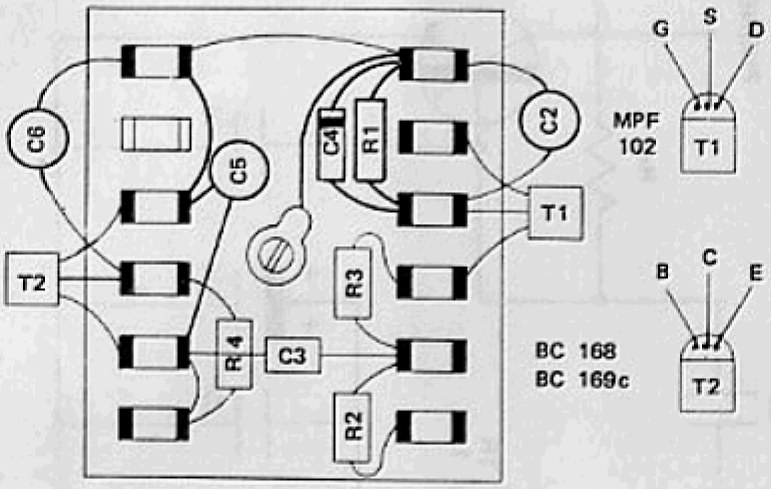


Fig. 1.

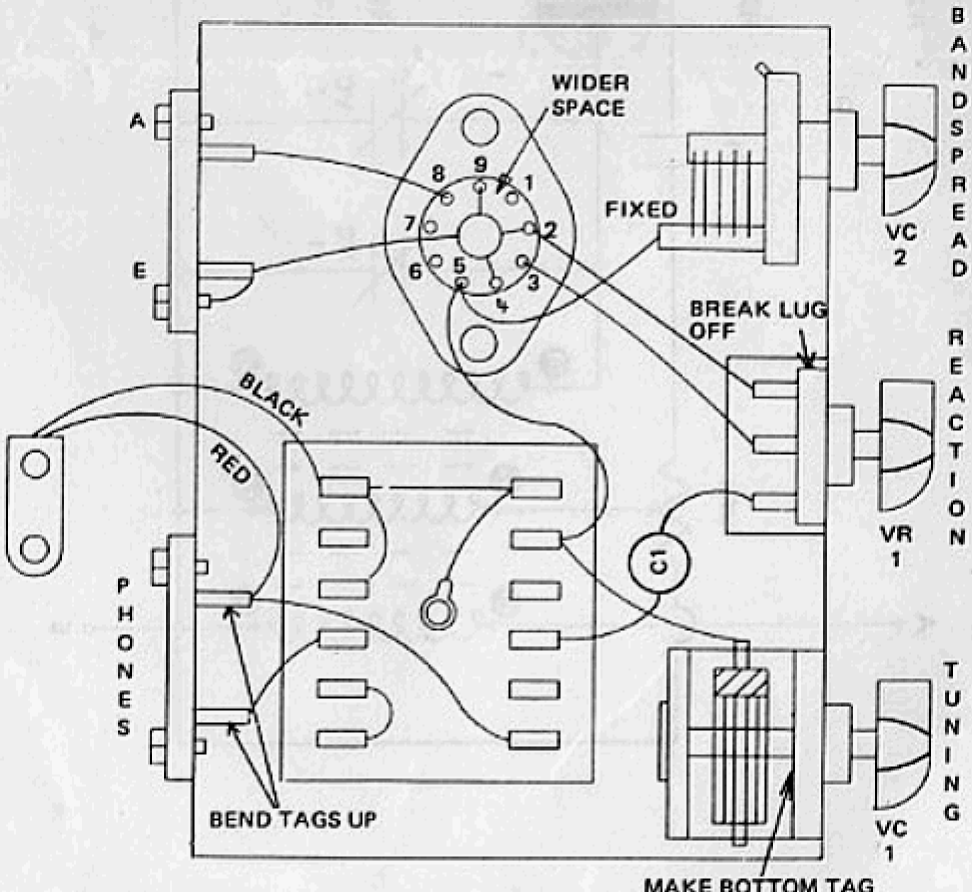


Fig. 2.

Layout and wiring diagram of the HAC receiver

hac

SHORT WAVE

RECEIVERS

Instructions for Constructing And Operating Model "T" Twin Transistor Receiver

Sole Manufacturers:
"H.A.C." SHORT-WAVE PRODUCTS
P.O. BOX 16, EAST GRINSTEAD, SUSSEX, RH19 3SZ

Original front cover of the HAC instruction booklet

From QRO minded to QRP power

This story is about how I became an enthusiast QRP radio amateur, although the plan was:
Build a 10 watt CW transceiver, perhaps I could make some QSO's with it and then build a RF amplifier of at least 100 watt, the more the better.
And indeed, a few weeks after obtaining my HF license, the transmitter for 80, 40 and 20 m was under construction. I tested the driver (0.5 W output) for its stability by connecting the collector of the driver transistor to a few meters of wire hanging in the shack. It looked OK and just for fun I transmitted 2x CQ.

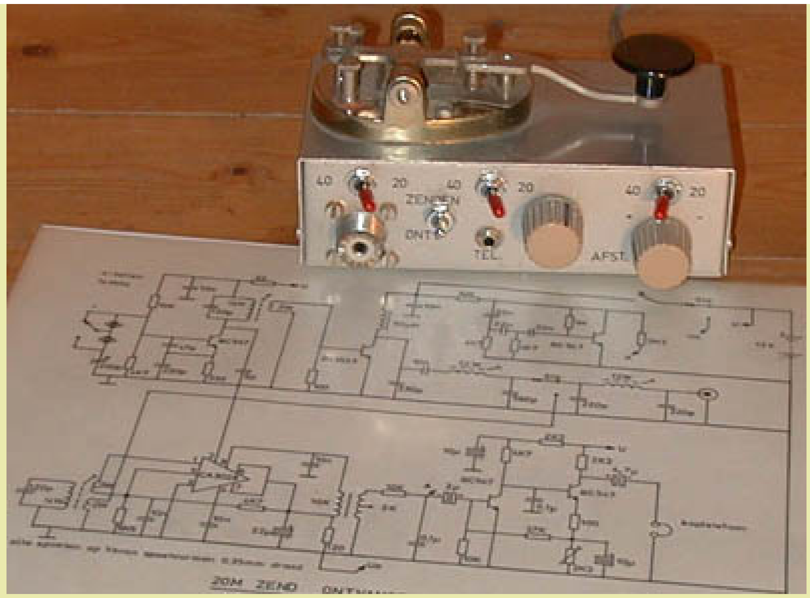
The general coverage shortwave receiver used for my first QSO in QRP.

The Barefooter, real barefoot technology!
Many QSO's were made during holidays.

And then it happened: A YU1 station called me on the short wave radio. I was so astonished and confused that it was due to my CW experience on 2 meters that the QSO came to a good end with rst 569! With an unmatched piece of wire connected to the driver running 0.5 watt real QRP power!

The whole weekend I was impressed by the fact that it was possible to make QSO's over 2000 km with such low power, a new QRP'er was born.
Well, the 10 watt amplifier gave not more than 5 watt but was accepted as the final stage. The 100 watt TS520 (it looked so nice) is never used a lot. Simple QRP equipment technology is my hobby now and I am astonished about what you can do with that.
But I do admit, although it is not my interest, I have respect for the hams making very big

stations with enormous antenna mast. I do surely not have enough energy to make such a station.

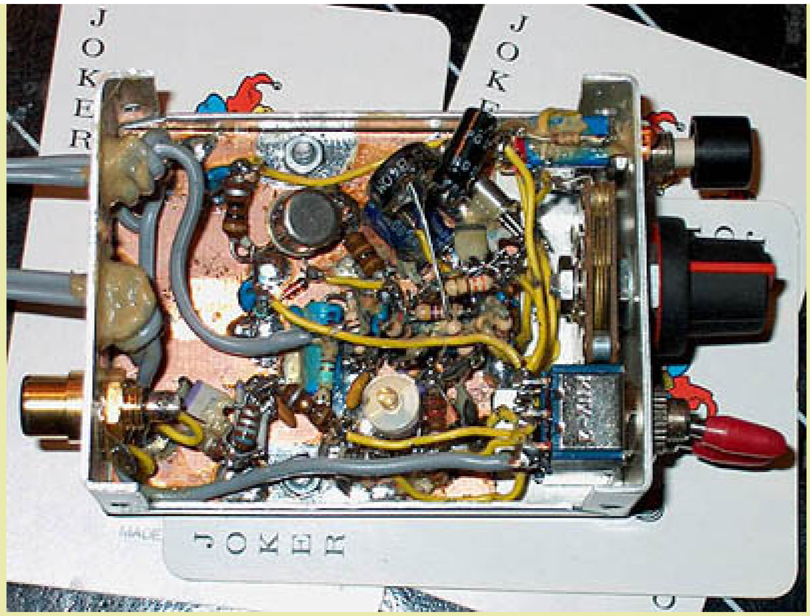


My second barefoot technology QRP rig for 20 and 40 meter.
Many QSO's were made while camping, even in the snow!

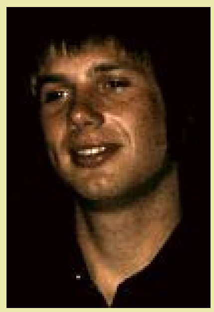
Back to Basics!
Hiking and QRP portable with the
simple 4 band "Happy Holidays" QRP rig.

A few weeks later I bought the book "Solid state for the radio amateur". A simple CW VXO tuned transceiver with 1 IC CA3028 and 3 transistors was described and this design was so different compared with the complex schematic diagrams I had seen, that I absolutely wanted to make and try it. It gave 0.6 watt on 14 MHz, supplied by 2x4.5V batteries. The Direct Conversion receiver worked very well and of course it had to be taken with me during holidays.
Almost every day it was possible to make contacts from Norway and Sweden with a ham nearby my home QTH. The antenna was a simple inverted V dipole, the centre at 4 meters height.

To be short: Nowadays I only have QRP equipment and made many QSO's even with South America with powers of less than 2 watt and simple dipole / random wire antenna's.
My hobby is making simple QRP equipment and experience what you can do with QRP.
All Barefoot technology or simple, cheap and harmless technology!



The ultra portable HIS transceiver.
Only for fans of real barefoot technology!


1977

BACK TO INDEX PA2OHH

Tune Around!

SEARCH

Topics For Technicians!
Loaded with info for new ham radio operators!

About Hamuniverse
Antenna Designs
Antenna Safety!
Ask Elmer
About Batteries
Band Conditions
Code Practice
Computer Help
Electronics
Emergency Power!
FCC Information
Frequency Guide!
Ham Exams!
Product Reviews
Hints and Projects
Humor
Ham Radio News!
Ham Radio Videos!
HF & Shortwave
License Study
Links
Midi Music
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RFI Tips and Tricks
Ham Satellites
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Shortwave Listening
SSTV
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Contact
Site Map
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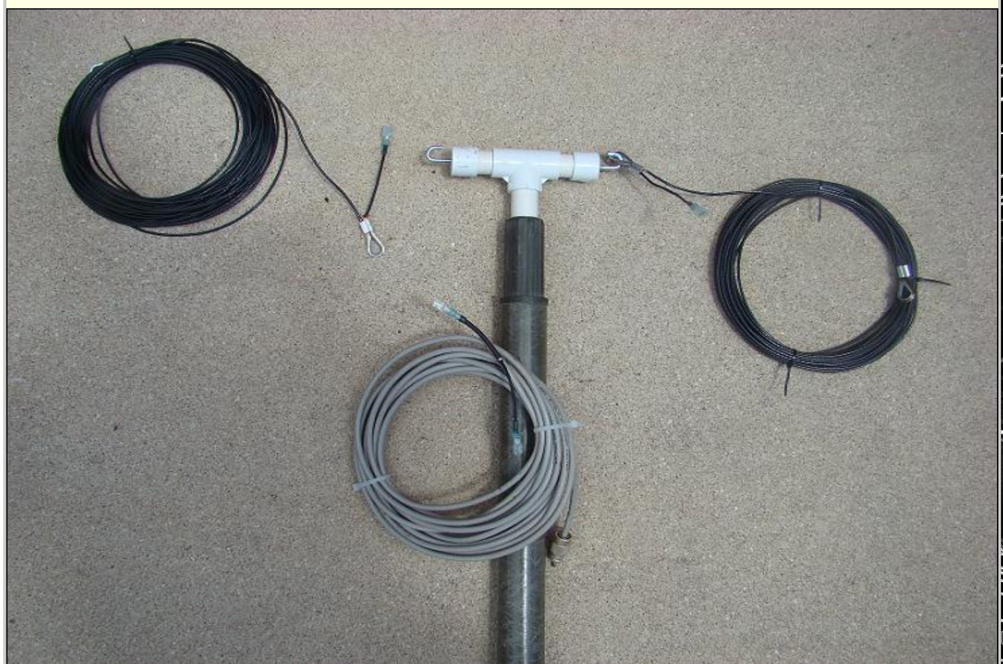
Submit a Project/Article!

ADVERTISING INFO

KL7BOB Field Day Antenna

5 Bands with a Tuner!

The photos in this article show an antenna I made for field day and erected as a NVIS inverted V. It was used on 5 hf bands with a tuner.



The apex was at 20 feet and the ends were 10 to 15 feet above ground. We worked 15m, 17m, 20m, 40m, and 80m using an LDG Z100 autotuner and a Kenwood TS 450 transceiver powered by a standalone 12 v marine battery. The dark pipe is a 4 foot section of fiberglass pipe and the white pipe and fittings are 3/4" PVC.

Here is a parts list for the center fitting (insulator) shown above:

3/4 " PVC pipe ~1 foot

3/4" PVC pipe caps 2 ea

3/4" PVC Tee 1 ea

3/16" x 1-1/2" "J" hooks w/ 2nuts 2 ea

3/16" flat washer 4 ea

3/16" lock washers 4 ea

PVC cement

Cut 2 pieces of 3/4" PVC pipe about 2" long and one piece about 8" long. Drill a 3/16" hole in the center of each pipe cap. Insert the threaded end of the J hook into the hole in the pipe cap and install a flat washer, a lock washer and a nut on the inside and outside of each pipe cap. Cement a 2" piece of PVC into each side of the T and cement the 8" piece to the bottom. Cement the pipe caps to the exposed ends of the PVC nipples making sure the hooks point up.
Photo below:

The legs of the dipole are not critical in length if you use a tuner. I cut mine to be resonant about 3850 (60 feet.) I used 14 ga stranded, insulated copper wire and installed a thimble and ferrule at each end. On one end strip 8" of insulation and on the other strip just enough insulation to install the thimble and ferrule. On the side to be connected to the coax leave the surplus stripped wire extending from the ferrule. Place a piece of heat-shrink tubing over the exposed wire. Place a heat shrink shrouded disconnect onto the end of the wire and crimp it closed. With a heat gun or hair dryer shrink the tubing snugly to the wire. You will need to make two of these legs the same length.

Strip about 4" from the end of a desired length of coax and separate the shield from the center conductor. Twist the shield and place a piece of heat shrink tubing over it. Place a heat shrink shrouded connector and crimp it closed. Likewise place a piece of heat shrink tubing over the center insulator of the coax and crimp a connector on the center conductor. Heat the tubing and connectors with a heat gun or hair dryer to complete the job.

You'll need the following hardware to construct the antenna legs:

14 ga stranded, insulated wire - 2 pieces 60 feet long

Cable thimbles 4 ea

Ferrules for crimping 4 ea

Heat-shrink tubing

Heat shrink shrouded male connectors 2 ea

Heat shrink shrouded female connectors 2 ea

===================================

There are many variations for this antenna that can quickly be made.

Hook the ends with the pig tail to the J hooks and connect to the coax. You can use any connector you want, I just found the slip connectors locally.

A number of variations for this antenna can quickly be made.
First, you can cut the dipole to suit your specific needs.
Second, you could make an off-center fed dipole like a Carolina Windom.
Third, you could make the legs longer and bolt the ends together to make a loop. I have since added an eyebolt to the top of the T so it can be suspended from a tree limb or hoisted up a flag pole. I used 3/16" braided nylon or bungee cords to secure the outboard ends of the antenna.

The advantage to the antenna is that you can wrap the legs and coax of the system separately so it is easier to pack. Also by varying the lengths of the legs you can have a custom antenna by assembling different components. Have fun playing with it. KL7BOB, Bob.

Editor notes:

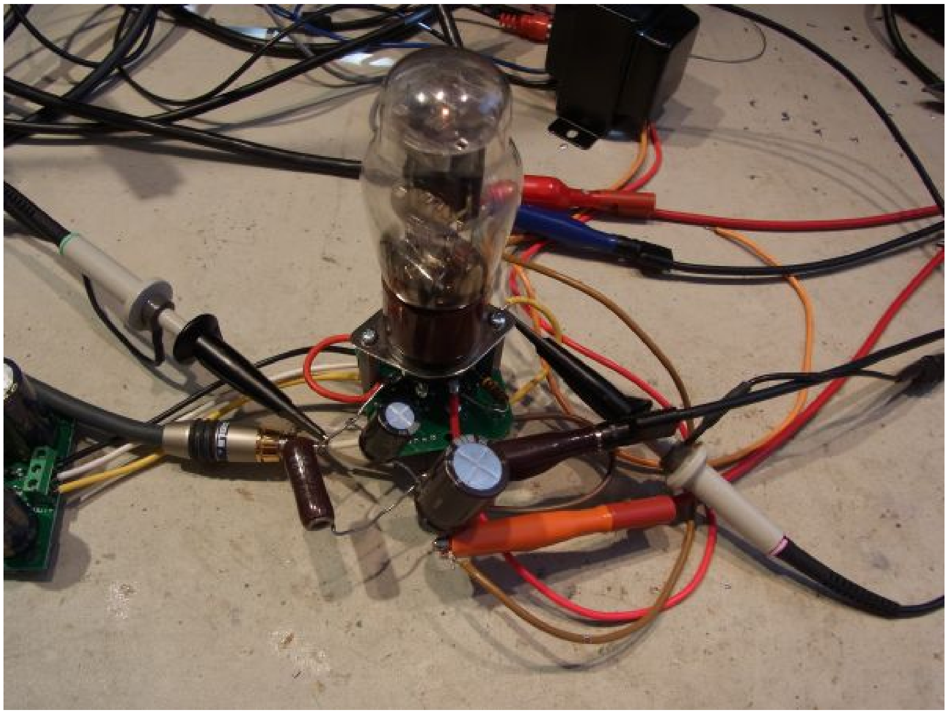
This is for the "newbies" out there.....As with all homebrew construction, you do not have to follow the exact methods Bob used for building this antenna.
If some parts that are listed in the article are not easy to get, then just use your "ham imagination and common sense skills". You will also notice in Bob's article, no mention of a power level OTHER than the output of a transceiver was used! Using power levels exceeding 100 watts may harm your tuner due to high swr on some bands.

Experimenting with antennas and their construction is what the fun of antenna building is all about.

DIY Audio Home

A Power Opamp Driver and Bias Supply PCB, and class-A2 experiments

(Note that the photos are hyperlinked to full-size photos in grisly detail)



I've wanted to try using a high-voltage power opamp (like the TI OPA452) to drive the grid of a tube for some time. Though the voltage swing is a bit limited (about +/-36V for the OPA452), it can source some current, so it seems like an interesting driver for class-A2. To facilitate this, I built a small PCB with a power opamp, as well as a small PCB to power it. Details on the boards are below.

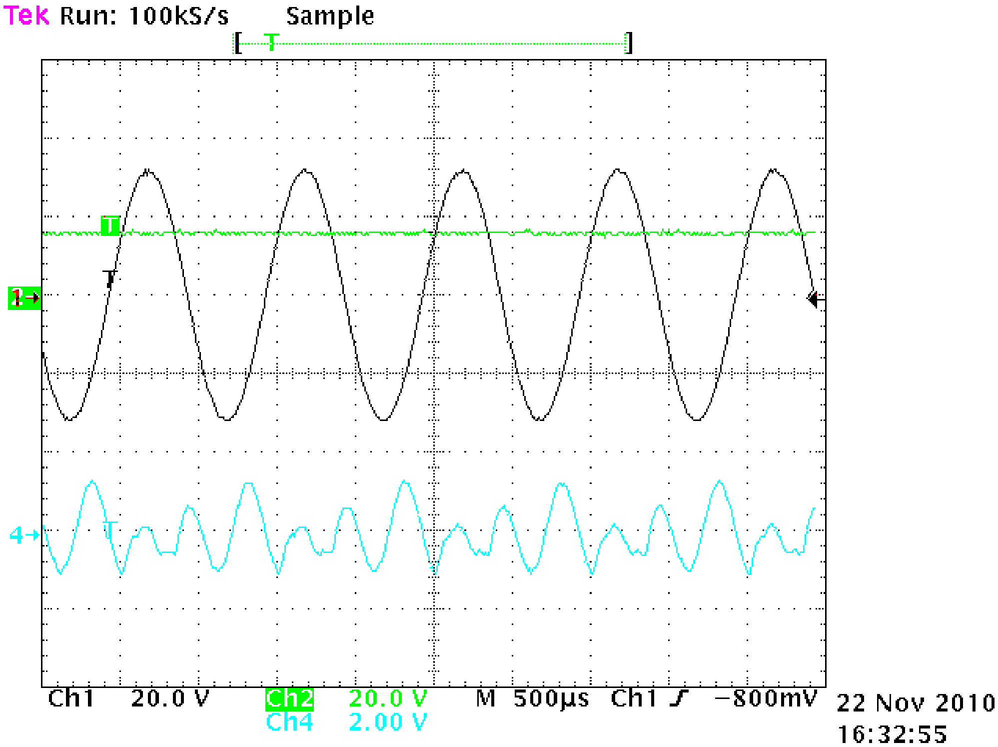
My thought was that I should be able to use this driver and a cheap transmitting tube driven in class A2 to make a cheap, simple amp. I have tried a number of tubes, but have more work to so.

So far I've only tried single-ended designs. I will eventually try some push-pull designs - you can set up one power opamp as inverting, and the other as non-inverting, and feed them the same input to make a push-pull amp. But I have not tried it yet...

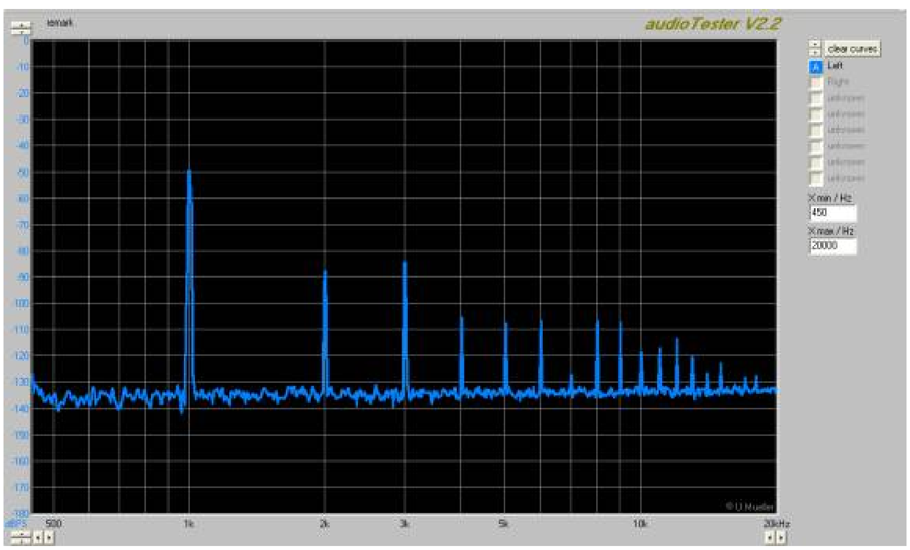
I tried the 2E26 and 1626 tubes in single-ended. The 2E26 worked fine, but really I got very little advantage over biasing in class A1. The 1626, however, worked pretty well in A2. The usual power output from this tube in A1 (as in the "Darling" amps) is about 750mW. Running in A2, I got almost double that - 1.4 watts at 5% THD. The opamp was hitting clipping at this point. 1W THD is about 2%. I used cathode bias (500 ohms) and a low B+ of 200V. This set the operating point at Vp = 174V, Ip = 30mA (just a little over the 5W limit).

Push-pull should get about double this or higher, if you push into AB2.

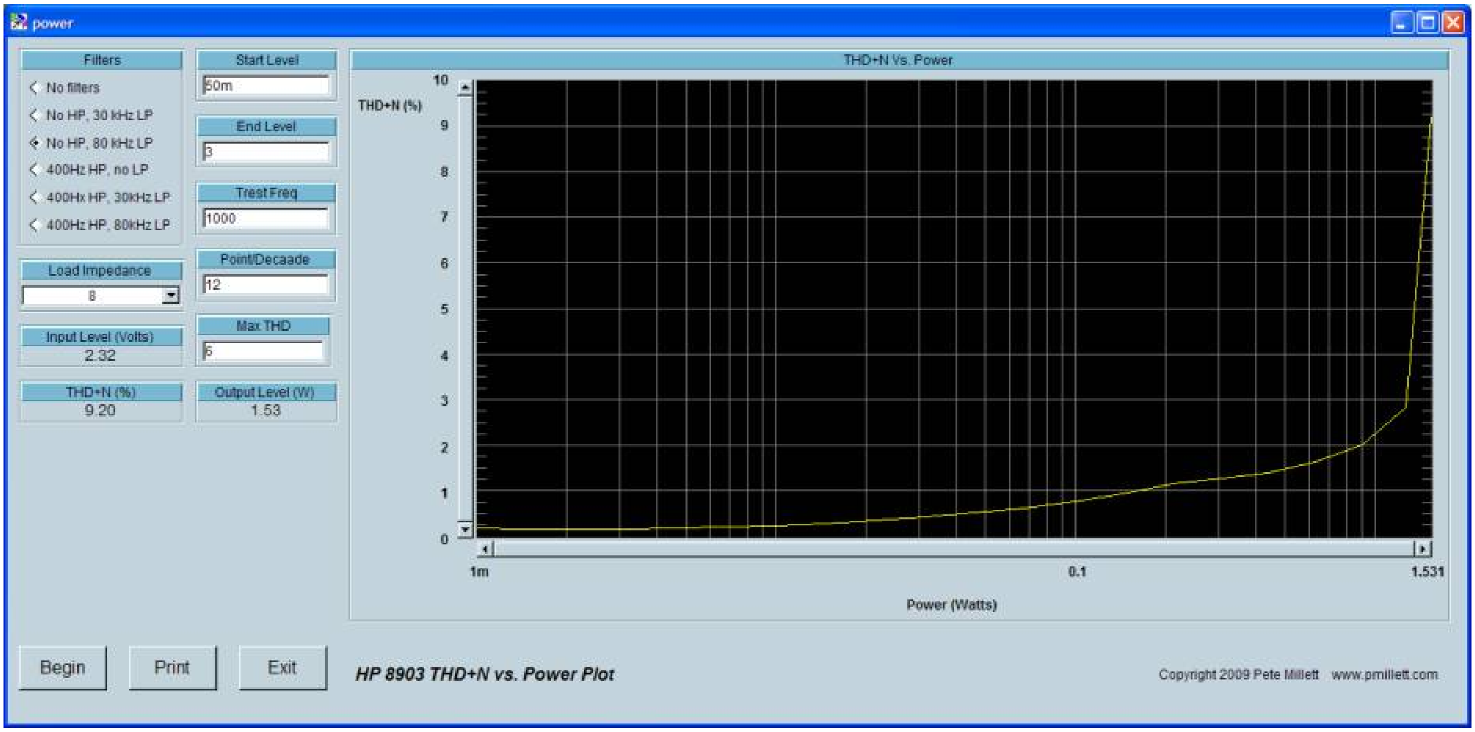
The scope shot below shows the grid (black) and cathode (green) of the 1626 tube. You can see it is running well into A2 operation, with the cathode sitting at about 15V and the grid swinging between ~-12V and +30V. The blue (cyan?) trace shows the distortion residual from the audio analyzer.



An FFT at 1W shows a mix of harmonics...



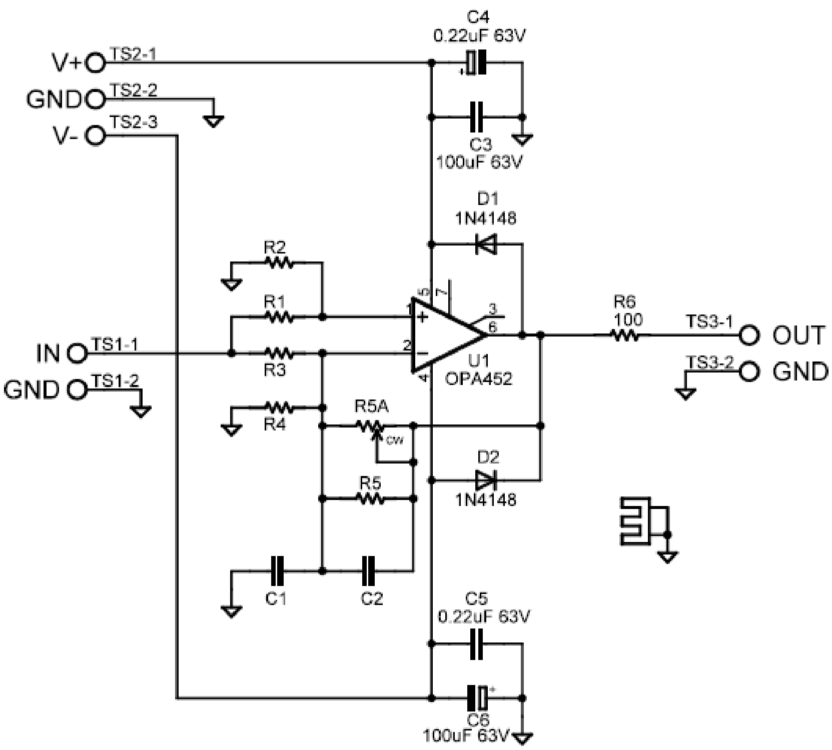
...and a power vs. THD plot looks pretty conventional, except you can see a slight flat spot at 0.2W. This is where the amp enters A2. I expected a bump UP in THD, but the THD actually flattened out a little in A2. As Spock would say: Fascinating...



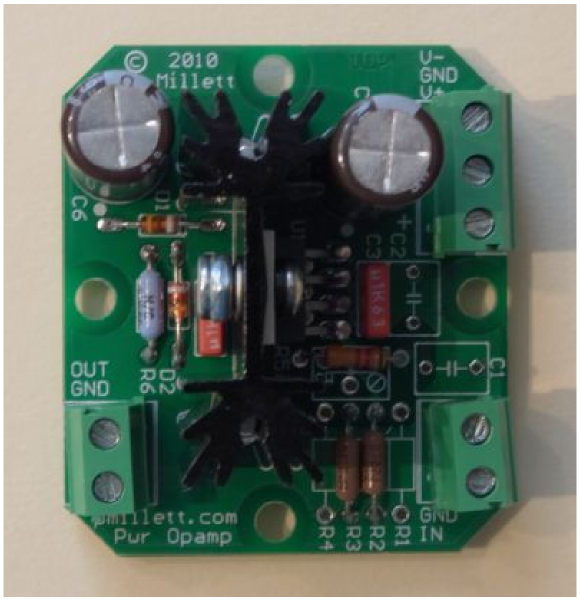
That's all for now, if I ever get time I'll try push-pull...

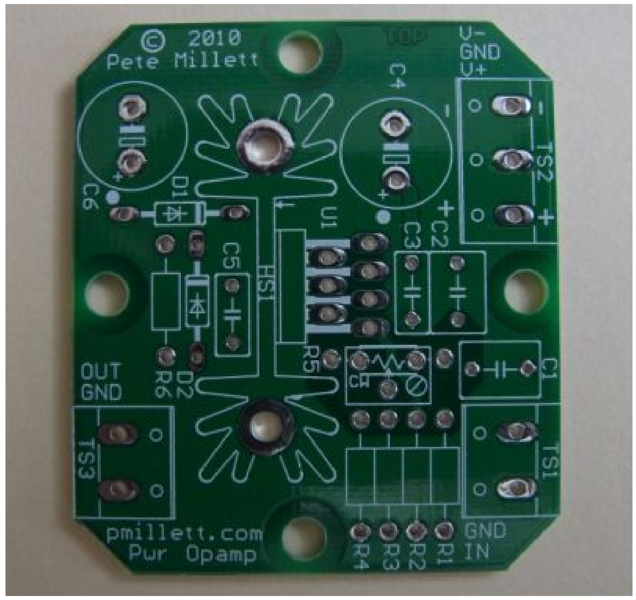
The power opamp PCB

To facilitate the experiments, I made a couple of small PCBs - one to carry a TO-220 package power opamp, and one to provide a small DC power supply. Here's the power opamp board schematic (or [download a PDF file](#)):



Basically just the opamp, decoupling caps, and positions for resistors and capacitors so you can make an inverting or non-inverting amp, and add some compensation (the caps) if needed. I made the PCB small, and positioned holes so you can mount it on the same holes that you use for a tube socket (in the picture above, the PCB is mounted to an octal socket). The PCB supports power opamps in a 7-pin TO220 package, including the +/-40V 50mA [OPA452 and OPA453](#), and the +/-30V [OPA547](#) (500mA) and [OPA548](#) (3A).





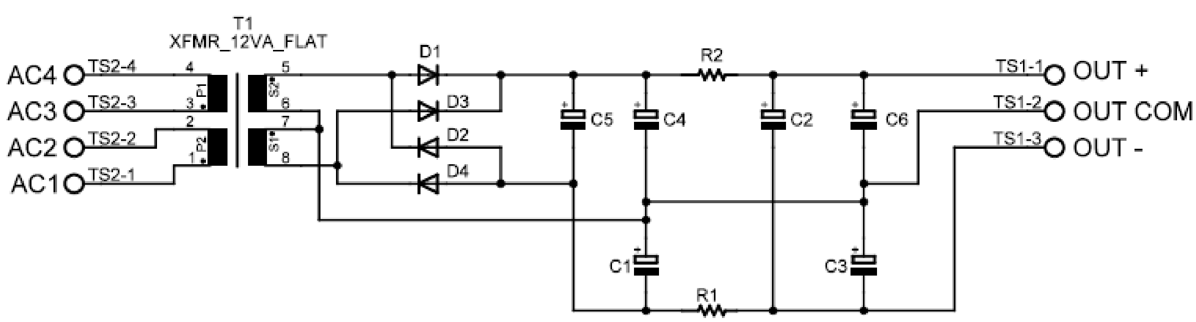
I made some measurements of the OPA452 itself. I was surprised to see that driving 20V RMS into 1k, the THD was under 0.005%, and was mostly second harmonic. that's pretty good for a power opamp! Made me think that a pair of these would make a pretty good headphone amp. Maybe switch to the OPA547 to drive 32 ohm headphones. Or use the OPA548 and drive speakers! it should work well as long as you don't get the thing too hot - the on-board heatsink is not huge.

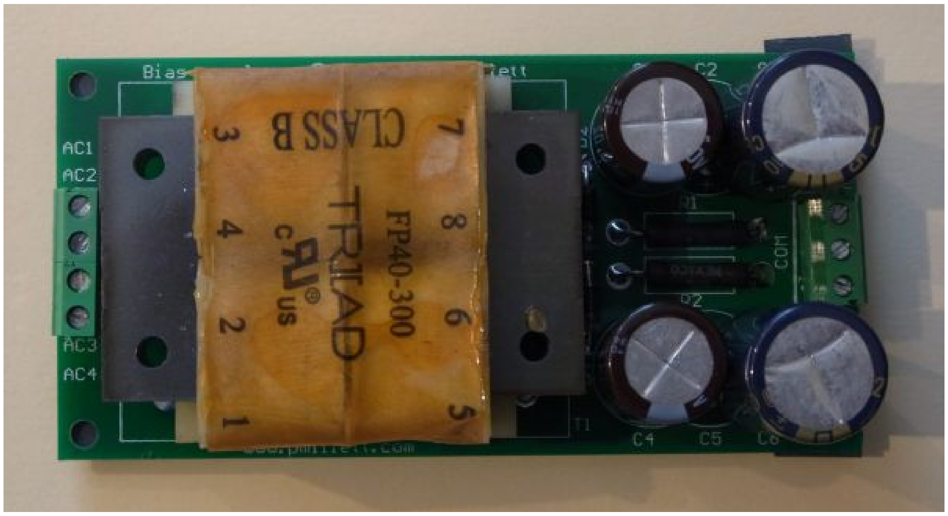
The board is so simple, I have not made a detailed BOM. If you want to build one, here are a few notes:

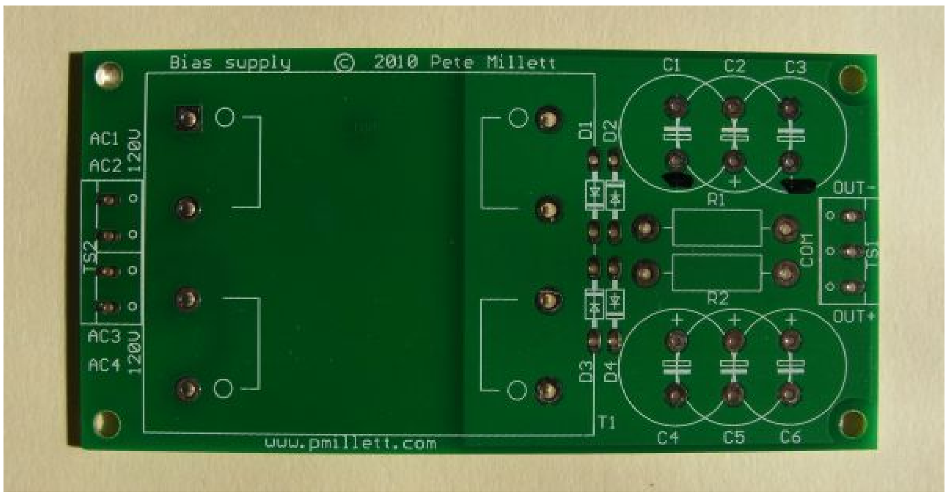
- I'll sell my extra PCBs on eBay
- All resistors are 1/4W.
- The heatsink is a 1.38" x 0.5" footprint, like the Aavid 513102B02500G.
- R5 can be a fixed resistor, or a trimpot. They occupy the same PCB space so only one or the other is installed.
- Look at the notes on the schematic (PDF version) for details on which parts to install for which configuration.
- Terminal blocks are standard 5mm or 0.2" centers, or you can solder wires in the holes.

The power supply PCB

The power supply is simple, designed so you can stuff it as a single-ended or bipolar (+/- voltage) supply. Seemed like a useful thing to have around, you could use it as an opamp supply (like here, I was generating +/-35V or so), or as a negative bias supply. It uses a 12 watt PCB-mount "flat" transformer. Here's the schematic (or a PDF file):







(Yes, I screwed up the polarity on C1 and C3 - see the magic marker? At least I realized it before there was an explosion...)

As above... This board is also so simple, I have not made a detailed BOM. If you want to build one, here are a few notes:

- I'll sell my extra PCBs on eBay
- You can use tools like PSUD II from Duncanamps to figure out what transformer voltage and what value caps and resistors you need.
- R1 and R2 are 1W wirewounds.
- The transformer is a 12VA flat transformer, like the FP40-300 from Triad, or similar parts from Signal, Hammond...
- Install C2 and C5 for a unipolar supply, C1, C3, C4, C6 for a bipolar (+/-) supply.
- Note the silkscreen error on the polarity of C1 and C3!
- Connect the inputs in series for 240V, parallel for 120V. See the transformer datasheet for instructions if its not clear.
- There is no fuse on the board - for safety, you need to insert one somewhere between the wall socket and the transformer.
- Terminal blocks are standard 5mm or 0.2" centers, or you can solder wires in the holes.

schweber

glos´sa-ry of com-put´er & in´te-gra´ted cir´cuit terms

ACTIVE ELEMENTS:
Those components in a circuit which have gain or which direct current flow: diodes, transistors.

ADDER:
Switching circuits which generate sum and carry bits.

ADDRESS:
A code designating the location of information and instructions in the main storage unit of the computer.

ANALOG COMPUTER:
A continuous-variable computer, or non-digital computer. A differential analyzer. Measures the effect of changes in one variable on all other variables in a system. Its operation is analagous to a slide rule.

AND:
A Boolean logic operator analogous to multiplication. Of two variables, both must be true for the output to be true.

ASYNCHRONOUS:
Operation of a switching network by a free-running signal which triggers successive instructions; the completion of one instruction triggers the next.

"BLACK BOX":
A useful mathematical approach to an electronic circuit which concerns itself only with the input and output, and ignores the interior elements, discrete or integrated.

BINARY:
A system of numerical representation which uses only two symbols, 0 and 1.

BIT:
Abbreviation for Binary Digit.

BUFFER:
A non-inverting member of the digital family which may be used to handle a large fan-out or to convert input and output levels. Normally a buffer is an emitter-follower type of circuit.

CERMET:
A material used in making thin film resistive elements. The first half of the term is derived from ceramic and the second half from metal.

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CHIP:
A single substrate on which all the active and passive elements of an electronic circuit have been fabricated utilizing the semiconductor technologies of diffusion, passivation, masking, photoresist, epitaxial growth. A chip is not ready for use until it is packaged and provided with terminals for connection to the outside world. Also called a die.

CLEAR:
To restore a memory or storage device to a "standard" state, usually the "zero" state. Also called Reset.

CLOCK:
A pulse generator which controls the timing of switching circuits and memory states, and equals the speed at which the major portion of the computer operates.

CML: CURRENT-MODE-LOGIC:
Operates in the unsaturated mode as distinguished from all the other forms which operate in the saturated mode.

COUNTER:
(a) A device capable of changing states in a specified sequence upon receiving appropriate input signals; (b) a circuit which provides an output pulse or other indication after receiving a specified number of input pulses. (Specific counters follow.)

COUNTER, BINARY:
A Flip-Flop having a single input. Each time a pulse appears at the input, the Flip-Flop changes state; called a "T" Flip-Flop.

COUNTER, RING:
A loop or circuit of interconnected Flip-Flops so arranged that only one is "on" at any given time and that as input signals are received, the position of the "on" state moves in sequence from one Flip-Flop to another around the loop.

DCTL: DIRECT-COUPLED-TRANSISTOR LOGIC:
Logic is performed by transistors.

DECIMAL:
A system of numerical representation which uses ten symbols 0, 1, 2, 3, ... 9.

DELAY:
Undesirable delay effects are caused by rise time and fall time which reduces circuit speed, but intentional delay units may be used to prevent inputs from changing while clock pulses are present. The delay time is always less than the clock pulse interval.

DIFFUSION:
A thermal process which introduces tiny amounts of impurities into the base material. A difficult process in solids though quite easy in fluids. Just drop a bit of coloring matter in a glass of water and the color will very gradually distribute itself throughout the water.

DIGITAL CIRCUIT:
A circuit which operates like a switch, that is, it is either 'on' or 'off'.

DIGITAL COMPUTER:
A discrete-variable computer which counts separate units.

DISCRETE:
Electronic circuits built of separate, finished components.

DTL: DIODE-TRANSISTOR-LOGIC:
Logic is performed by diodes. The transistor acts as an amplifier; and the output is inverted.

EPITAXIAL GROWTH:
A chemical reaction in which silicon is precipitated from a gaseous solution, and grows upon the surface of a silicon wafer present in the gaseous solution.

EXCLUSIVE "OR":
The output is true if either of two variables is true, but *not* if both are true.

FALL TIME:
A measure of the time required for a circuit to change its output from a high level (1) to a low level (0).

FAN-IN:
The number of inputs available on a gate.

FAN-OUT:
The number of gates that a given gate can drive. The term is applicable only within a given logic family.

FEB:
Acronym for Functional Electronic Block. Another name for a monolithic integrated circuit.

FLIP-FLOP:
An electronic circuit having two stable states, and having the ability to change from one state to the other upon the application of a signal in a specified manner. See specific types below.

FLIP-FLOP, "D":
D stands for delay. A flip-flop whose output is a function of the input which appeared one pulse earlier, that is, if a 1 appears at its input, the output a pulse later will be a 1.

FLIP-FLOP, "J-K":
A fllip-flop having two inputs designated J and K. At the application of a clock pulse, a 1 on the J input will set the flip-flop to the 1 or "on" state; a 1 on the K input will reset it to the 0 or "off" state, and 1's simultaneously on both inputs will cause it to change state regardless of what state it had been in.

FLIP-FLOP, "R-S":
A flip-flop having two inputs designated R and S. At the application of a clock pulse, a 1 on the S input will set the flip-flop to the 1 or "on" state, and 1 on the R input will reset it to the 0 or "off" state. It is assumed that 1's will never appear simultaneously at both inputs.

FLIP-FLOP, "R-S-T":
A flip-flop having three inputs, R, S, and T. The R and S inputs produce states as described for the R-S flip-flop above; the T causes the flip-flop to change states.

FLIP-FLOP, "T":
A flip-flop having only one input. A pulse appearing on the input will cause the flip-flop to change states.

GATE:
A circuit having two or more inputs and one output, the output depending upon the combination of logic signal at the inputs. There are four gates called: AND, OR NAND, NOR. The definitions below assume positive logic is used.

GATE, AND:
All inputs must have 1-state signals to produce a 1-state output.

GATE, NAND:
All inputs must have 1-state signals to produce an 0-state output.

GATE, NOR:
Any one input or more having a 1-state signal will yield an 0-state output.

GATE, OR:
Any one input or more having a 1-state signal is sufficient to produce a 1-state output.

GIGO:
An acronym used to describe a computer whose operation is suspect. (Garbage in, garbage out.)

HALF SHIFT REGISTER:
Another name for flip-flop.

HOLE:
An electron vacancy; an unfilled state in a valance-band of electrons. A positive charge.

HYBRID:
A method of manufacturing integrated circuits by using a combination of the monolithic and thin film methods.

IMPURITIES:
Material added to silicon or germanium in order to create a P-type section or N-type section. Examples of impurities: boron, phosphorous, arsenic.

INTEGRATED CIRCUIT:
The Electronic Industries Association defines semiconductor integrated circuit as – "the physical realization of a number of electrical elements inseparably associated on or within a continuous body of semiconductor material to perform the functions of a circuit".

INVERTER:
The output is always in the opposite logic state of the input. Also called a NOT circuit.

ION:
When an atom which is electrically neutral acquires one or more additional electrons, or loses one or more of its electrons, the resulting state of charge is called an ion.

JUNCTION:
A junction is formed when an N-type crystal is brought into close contact with a P-type crystal creating a boundary between them.

LINEAR CIRCUIT:
A circuit whose output is an amplified version of its input, or, whose output is a pre-determined variation of its input.

LOGIC:
A mathematical approach to the solution of complex situations by the use of symbols to define basic concepts, also called Symbolic Logic. The three basic logic symbols are "and", "or", and "not". When used in Boolean Algebra these symbols are somewhat analogous to addition and multiplication.

MEMORY:
A storage device into which information can be inserted and held for use at a later time.

MICROCIRCUIT:
Another name for integrated circuits.

MICROELECTRONICS:
Another name for integrated circuits.

MONOBRID:
A method of manufacturing integrated circuits by using more than one monolithic chip within the same package.

MONOLITHIC:
"One-stone." A single flat-surfaced chip of silicon onto which patterns may be drawn, scribed, diffused, etc., the result being a simple chip of material into whose surface has been formed transistors, diodes, resistors and capacitors.

MULTIPLE CHIP:
Another name for hybrid type circuit manufacture.

NEGATIVE LOGIC:
The reverse of POSITIVE LOGIC.

"NOT":
A Boolean logic operator indicating negation. A variable designated "not" will be the opposite of its "and" or "or" function. A switching function for only one variable.

"OR":
A Boolean operator analogous to addition. (Except that two truths will only add up to one truth.) Of two variables, only one need be true for the output to be true.

PARALLEL OPERATION:
Pertaining to the manipulation of information within computer circuitry, in which the digits of a word are transmitted simultaneously on separate lines. Faster than serial operation, but requires more equipment.

PASSIVE ELEMENTS:
Those components in a circuit which have no gain characteristics: capacitors, resistors, inductors.

POSITIVE LOGIC:
The more positive voltage (or current level) represents the 1-state; the less positive level represents the 0-state.

PROPAGATION DELAY:
A measure of the time required for a change in logic level to propagate through a chain of circuit elements.

PULSE:
A change of voltage or current of some finite duration and amplitude. The duration is called the pulse width or pulse length; the magnitude of the change is called the pulse amplitude or pulse height.

RCTL: RESISTOR-CAPACITOR-TRANSISTOR-LOGIC:
Same as RTL except that capacitors are used to enhance switching speed.

REGISTER:
A device used to store a certain number of digits within the computer circuitry, often one word. Certain registers may also include provisions for shifting, circulating, or other operations.

RISE TIME:
A measure of the time required for a circuit to change its output from a low level (0) to a high level (1).

RTL: RESISTOR-TRANSISTOR-LOGIC
Logic is performed by resistors. The transistor produces an inverted output from any positive input.

SERIAL OPERATION:
Pertaining to the manipulation of information within computer circuitry, in which the digits of a word are transmitted one at a time along a single line. Though slower than parallel operation its circuitry is considerably less complex.

SHIFT REGISTER:
An element in the digital family which utilizes flip-flops to perform a displacement or movement of a set of digits one or more places to the right or left. If the digits are those of a numerical expression, a shift may be the equivalent of multiplying the number by a power of the base.

SIMULATION:
Testing contingent proposals on computers in advance of implementation.

SKEWING:
Refers to time delay or offset between any two signals.

SLEWING RATE:
Refers to rate at which output can be driven from limit to limit over the dynamic range.

SYNCHRONOUS:
Operation of a switching network by a clock pulse generator. Slower and more critical than asynchronous timing but requires less and simpler circuitry.

THIN FILM:
A method of manufacturing integrated circuits by depositing thin layers of materials to perform electrical functions; usually only passive elements are made this way.

TTL: TRANSISTOR-TRANSISTOR-LOGIC:
A modification of DTL which replaces the diode cluster with a multiple-emitter transistor.

WORD:
The term "word" denotes an assemblage of bits considered as an entity in a computer.

SOURCES:
Most of the information contained in this glossary was obtained from the literature of microcircuit manufacturers, particularly Fairchild, General Electric, Motorola, *and* Westinghouse.

SCHWEBER
ELECTRONICS

WESTBURY, N. Y. 11591 • (516) ED 4-7474

[DIY Audio Home]

Wheatfield Audio HA-1 Headphone Amp

So, ya wanna build a headphone amp?

This is the Wheatfield Audio HA-1 tube headphone amp, which I designed it to be an "affordable" alternative to the more expensive HA-2. I manufactured it for a couple of years, and HeadRoom sold it. When I finally came to the realization that I was perhaps one of the world's worst businessmen, I sold it - the design, rights, and inventory - to HeadRoom.

Headroom built and sold some more, but eventually discontinued it.

So a couple of years later, on a whim, I asked Tyll (the chief HeadRoomer) if he would care if I put the design into the public domain, since neither of us had any plans to do anything commercial with it. "Sure, no problem" was his response... so here it is!

PLEASE READ - Commercial usage of information on this site:

I consider all the information that I post here to be in the public domain. So, you can use it however you want, for commercial or non-commercial use.

That said, I would appreciate it if you at least let me know if you are going to use any of the circuits or especially PCB Gerber files to make commercial products, or to sell bare PCB's.

There are some cases where products are being sold not only with my permission, but active involvement. The "Millett Hybrid" effort and others at HeadFi are examples (and excellent models of how the DIY community should work, in my opinion). There are other cases where I have asked vendors to sell PCB's as a service to hobbyists. And there are other cases where companies are manufacturing and selling PCB's, chassis, etc. without contacting me at all.

In ALL of these cases, I make no profit from any of the sales. Zero, zip, nada. I have a normal "day job" that pays the bills, this is strictly a hobby with me. So please do not expect me to provide the level of technical support that you might expect when buying a product. I try and help, but it sometimes takes me days - even weeks if I'm traveling for work - to respond.

Thanks for your indulgence in reading this!

The HA-1 is similar to the HA-2 in that it is a 2-stage tube amp, using a regular common-cathode voltage amp stage directly coupled to a cathode follower. The HA-1 uses a 12AU7 as the voltage amp tubes, and a pair of 7044 dual triodes (parallel connected) for the cathode follower. The result is quite a low output impedance for a tube OTL, and this can drive even 32 ohm headphones.

I'm posting all of the original design data that I found, including data to make the PCB, the costed bill of materials including vendor data, and a mechanical CAD file that has all of the individual metal case parts included in it (on separate layers).

I don't have any parts or PCB's for sale. If you, or somebody you know, wants to fab and sell PCB's, or even kits, to the DIY community, please contact me at:

pete@pmillett.com

So here lies everything you need to build them for yourself:

The schematic: 37k PDF file

BOM (Bill Of Materials): 20k XLS spreadsheet

NEW 4/30/08 - *Custom power transformer specification:* 46k PDF file

Schematic and PCB source files (OrCAD .DSN and PADS-PCB .JOB files): 44kB ZIP archive (see the CAD page for tools)

Or, *Gerber files to fab PCB's:* 66kB ZIP archive

Full mechanical drawing: 271kB AutoCAD .DWG file, or 626kB R12 .DXF file

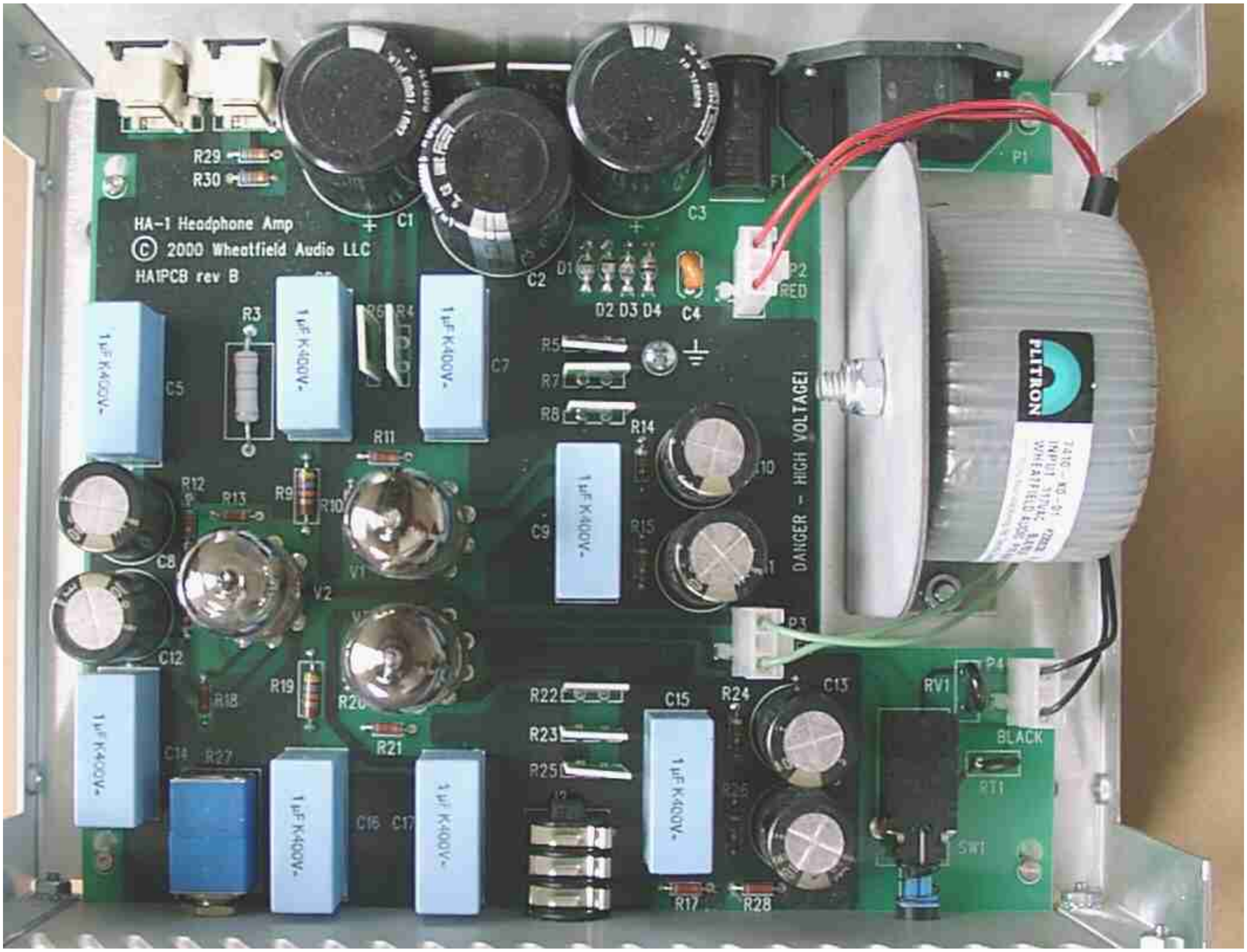
Transformer spec, 447kB PDF file

User's Manual, 115kB PDF file

More pictures...

This is an inside view showing the original custom EI-core transformer (which came out at too high a voltage, hence the big brown resistor you see sitting on the transformer). In this small case, I had a hard time getting the noise out, so I eventually switched to a toroidal power transformer.

Here's the inside with the custom transformer made by [Plitron](). If you want to order it, they should still have the design - you might have to buy a bunch of them though. The Plitron design number is 7410-X0-01. They cost me about $45 each in lots of 25 pieces - expensive - but with this the amp was very quiet.



The 7044 tube (GE mfg, this one branded Penta), and JJ ECC82, which is what shipped in the amp...

Here are the specs published at the time:

General

Input impedance: 50k ohms
Input connections: Unbalanced, gold-plated RCA
Tube complement: 1x ECC82 (12AU7), 2x 7044
Power supply: Silicon rectifier, 3-stage RC filter
Power requirement: 117V, 60 Hz, 50W
Dimensions: 9.5” W x 3.6” H x 7.1” D
Weight: TBD
Warranty: One year on all parts, including tubes

As a Headphone Amplifier

Frequency Response :
600 ohm load: <9Hz - 250kHz +/- 3 dB
32 ohm load: 12Hz – 250kHz +/- 3 dB
THD+N (1kHz, 1V RMS out, 100 ohm load): <0.12%
Noise: TBD
Maximum output voltage (5% THD):
600 ohm load: 13V RMS
32 ohm load: 1.5V RMS
Output impedance: Approx. 35 ohms
Output connection: Standard ¼” stereo headphone jack

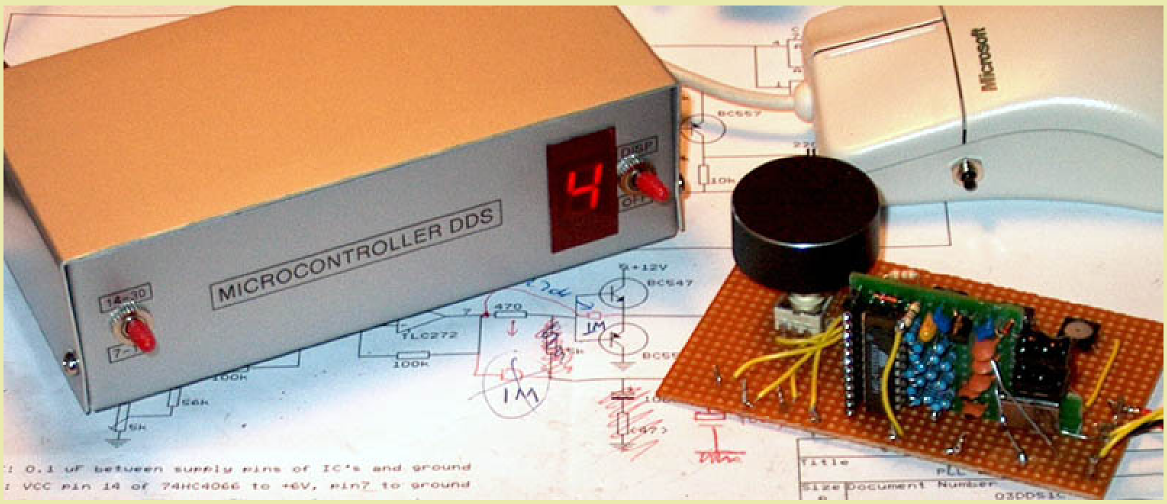
As a Pre-Amp

Frequency Response (10k ohm load) :
<9Hz - 250kHz +/- 3 dB
<9Hz - 95kHz +/- 1 dB
THD+N (1kHz, 1V RMS out, 10k ohm load): <0.18%
Noise: TBD
Maximum gain: 28 dB
Maximum output voltage (5% THD):
10k ohm load: 15V RMS
600 ohm load: 8V RMS
Output impedance: Approx. 35 ohms
Output connections: Unbalanced, gold-plated RCA

EXPERIMENTAL DIRECT DIGITAL SYNTHESIS BASED ON A MICROCONTROLLER AND PHASE LOCKED LOOP

(2003 and modified in 2004)

NEDERLANDS ARTIKEL BENELUX QRP CLUB



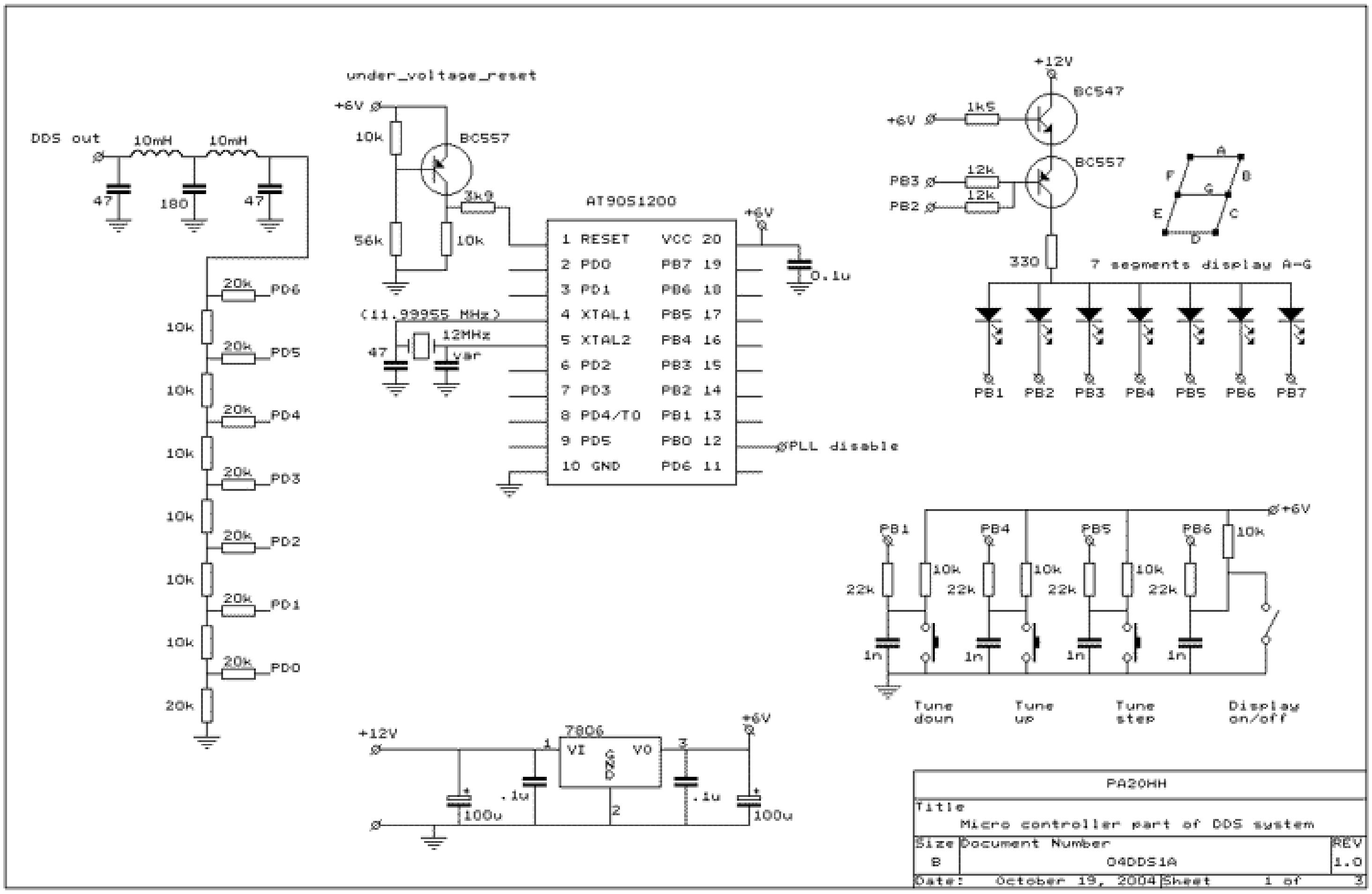
The Microcontroller DDS with PLL from 6 to 30 MHz and the original DDS of Ton, PA0KLT with rotary encoder in a test setup.

DDS with a microcontroller
In the Benelux QRP club magazine nr. 103 (September 2002) was an article from Ton, PA0KLT about a QRP tuning system. The system works with a DDS made with a micro controller! The advantage is that you do not need to buy a DDS chip that is expensive, difficult to get and with the soldering problems of the small SMD pins. A cheap simple microcontroller does the job. It even controls the rotary encoder for tuning! However, just as with a normal DDS, a second device is required to read the frequency.

Frequency read out added to the microcontroller DDS circuit
In my version I added a simple one 7 segments display as a frequency display. So the usual combination of a DDS chip plus a microcontroller to control the DDS and display the frequency is now reduced to just one microcontroller. This single microcontroller works as a DDS, it displays the frequency on a 7 segments display and it scans the tuning buttons.

Suppression of DDS spurious
A problem of using only 7 bits and the low clock frequency of 923 kHz is that there are some spurious signals. However, they are efficiently suppressed in the PLL loop filter! If there are some left, they are weak and all within the audio band. A big advantage is that they never cause any reception of unwanted signals as is the case with a "normal" DDS without PLL. And they are completely gone when the RF frequency is tuned only 15 to 30 Hz up or down.

The Microcontroller DDS



The DDS with microcontroller and display.
Output frequency 46875 Hz to 234375 Hz (RF frequency 6 to 30 MHz).
big diagram

The DDS Microcontroller
The heart of the DDS is the fast but simple and cheap microcontroller AT90S1200. The crystal frequency is 11999.55 MHz so a 12 MHz crystal can be used. The DDS controls a VCO with a frequency of 6 to 30 MHz. The frequency of this VCO is divided by 128 and locked to the DDS with a phase locked loop circuit. The frequency range of the DDS is then 46875 Hz to 234375 Hz.
One loop is 13 machine cycli so the clock frequency of the DDS is 11999.55 / 13 = 923.04 kHz. The output form is not a sine but a triangle. The output port D, bits 0 to 6, is together with the resistor network, the simple 7 bits D/A converter.
The L/C low pass filter has a cut off frequency of 200 kHz. Perhaps that an extra section might improve the performance a little, as the cut off frequency is rather high compared to half the clock frequency of 923 kHz. Ports B1, B4, B5, B6 are also used as inputs. In that case, the LED display is switched off by the BC557 transistor. The transistor is switched on by activation of one of the ports B2 or B3. The segments B and C of the 7 segments LED are connected to these ports and one of the two is always on when a digit is displayed. Instead of a current limiting resistor per segment, one resistor is used. You should expect that the brightness varies a lot, depending on the number of segments activated. But in practice, it is hardly noticeable.
The LED is connected to the +12V to avoid variation of the stabilized 5V supply voltage due to the LED currents.

Disabling the PLL to avoid problems at high DDS output frequencies
Pin B0 disables the PLL during certain software routines when the clockspeed goes down to 1/8x 923 kHz. With such a low clock speed that is even much lower than the highest DDS output frequency of 1/4x the clock speed, the DDS output is heavily distorted for a moment. Without disabling the PLL (only 255 us) during these routines, you can hear that as a loud click or "tjoop".

Tuning is done with 3 switches, two for tuning, one for the tuning speed.
I took an old mouse for it, only the 3 switches are used.
An extra switch is added as it was a two-button mouse.

Tuning of the DDS
Tuning of the DDS is done by 3 switches of an old 3 button mouse (only the switches are used) and works very pleasant. Two buttons are for tuning the frequency up or down, the third one is for the tuning speed. There are 6 tuning speeds of the final VCO (that works at a 128x higher frequency): 15.625 Hz, 31.25 Hz, 62.5 Hz, 1 kHz, 10 kHz and 100 kHz. Pushing the speed button together with one of the tuning buttons will change the speed, it is displayed on the 7 segments LED display. When pushing the frequency up or down button, 9.1 of such frequency steps per second are executed.
When executing a frequency step, the DDS runs 9.1x per second at 1/8x the normal clock speed of 923 kHz. The same applies for when the frequency display is active. There is an extra switch to switch off the frequency display for the cleanest RF signal.

How can you read the frequency with only one display?
Very simple if you know it!

Frequency display
For the 3 lower tuning speeds, the kHz value of the frequency is displayed.
When the 10 kHz or 100 kHz tuning speed is selected, the MHz + 100 kHz value of the frequency is displayed. That works as follows:

For a frequency of 21.345 MHz and 10 kHz - 100 kHz tuning speed:
Display "2" during 0.5 second
Display off during 0.1 second
Display "1" during 0.3 second
Display off during 0.1 second

Display "3" during 0.3 second
Then the display is off during 5 seconds and the frequency is displayed again.

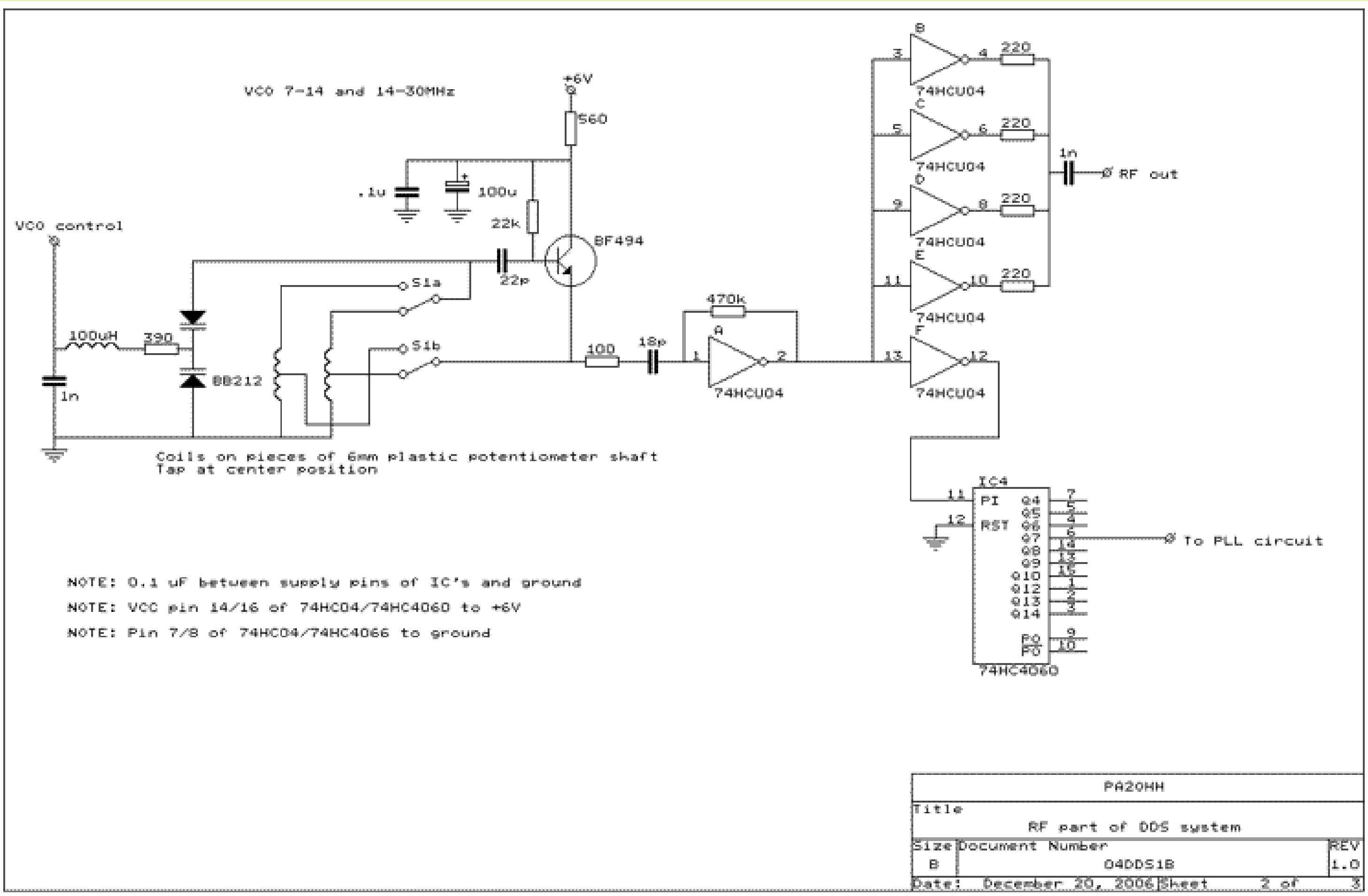
For a frequency of 21.345 MHz and one of the lower tuning speeds selected:
Display "3" during 0.5 second
Display off during 0.1 second
Display "4" during 0.3 second
Display off during 0.1 second
Display "5" during 0.3 second
Then the display is off during 5 second and the frequency is displayed again.

The display is off during 5 seconds but the frequency is displayed immediately after the frequency up-down buttons are released.

The first digit is displayed a little longer than the others as this gives a more pleasant reading.

When the speed button is pressed, the speed (1 to 6) is displayed. It steps slowly (0.5 seconds per step) up or down when you also push one of the tuning buttons.

The VCO

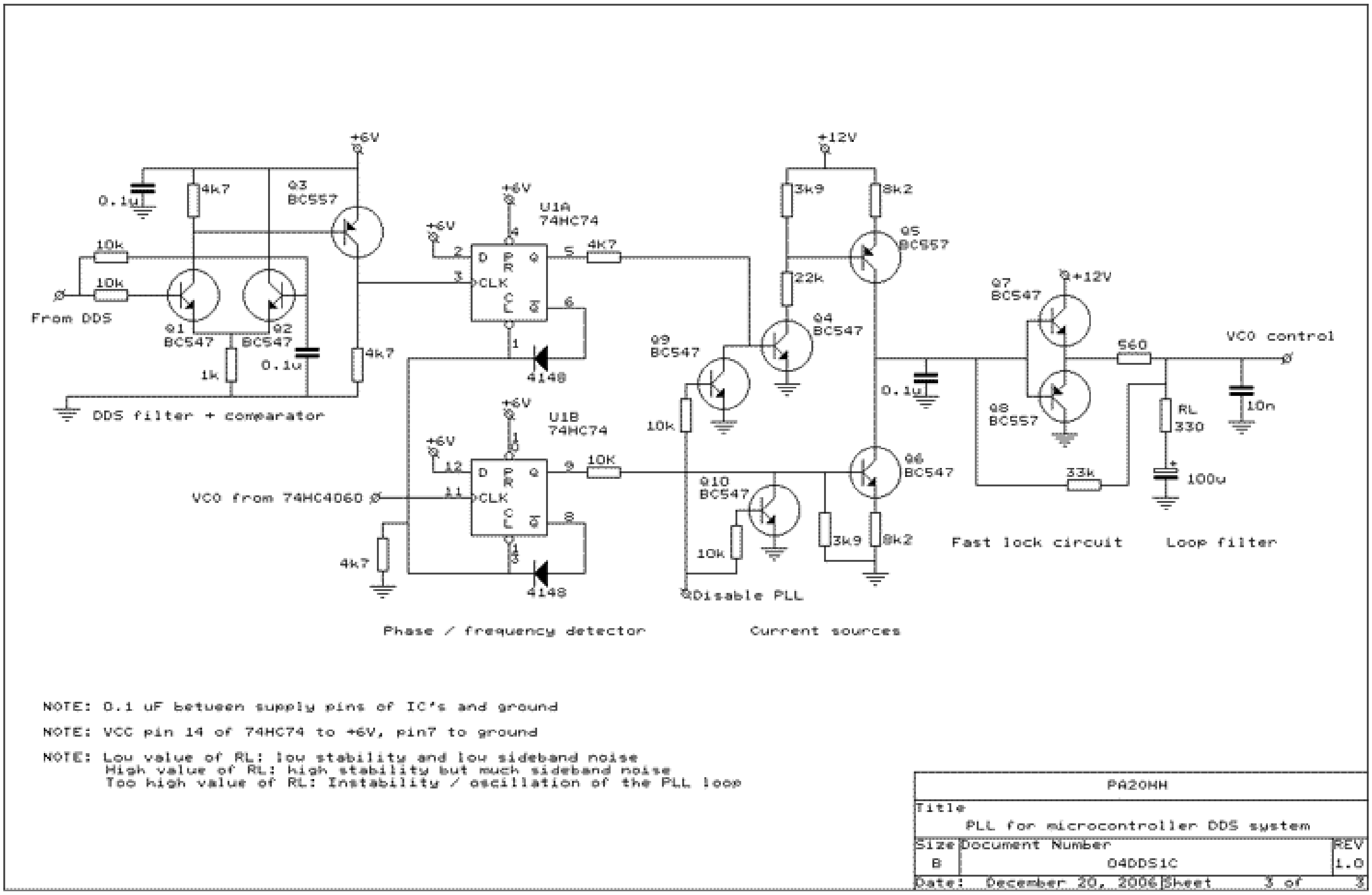


The VCO with output driver and /128 divider.
big diagram

The VCO with output driver and /128 divider
What can I say about it, just a VCO with a transistor and a switch for the two frequency ranges. The VCO is

buffered with a 74HCU04 (perhaps a 74HC04 can also be used) and the 74HC4060 divides the VCO frequency by 128. This signal goes to the PLL circuit. Simple indeed!

The PLL circuit



The phase locked loop circuit with the phase/frequency detector with charge pump.
Only standard, general available components are used.
big diagram

Phase locked loop
The first design of the PLL was with a sampling system and was designed to have a fast control loop of the VCO. Click here to see that old version. However, a fast loop is not required but what we need is a loop especially suited for suppression of spurious signals. The usual circuit with a phase / frequency detector with a charge pump is better for that purpose and does not have the disadvantage of locking on harmonic frequencies. It can also work with much higher DDS frequencies than the sample system. And a higher DDS output frequency gives a faster control loop with less spurious signals.

Standard components for the PLL
This is the usual circuit with a phase-frequency detector with set-reset flip flops. The idea was to use a 74HCT9046 phase detector IC. But this part is not available anymore. That was for me the reason to make such a phase/frequency detector with use of "standard" general available components.
Another advantage is that you have access to components and connections that normally are not accessible. It is for example possible to disable the charge pump during certain software routines when the DDS output signal is distorted.

The PLL in detail
The 3 transistors Q1, Q2 and Q3 are a comparator circuit. The base of Q2 is connected to the average DC voltage of the DDS circuit (averaged by the 10k resistor and the 0.1 uF capacitor).

The square wave output of the comparator circuit is connected to the clock input of the D-flipflop U1A. These inputs do have a hysteresis circuit and do not need a perfect square wave signal. The VCO signal (divided by 128) is connected to the second D-flipflop U1B. When both D-flipflop outputs are "1", they are resetted by the AND circuit consisting of the two diodes 1N4148.
When locked, the D-flipflops with AND circuit do work as a phase detector, when unlocked, they work as a frequency detector.

The flipflop outputs do control the two current sources Q5 and Q6, who are charging the 0.1 uF charge pump capacitor. The current sources together with the 0.1 uF capacitor do also effectively suppress all spurious signals. The current is set by the values of the 8k2 ohm resistors. The voltage accross these resistors is 1V, the output control voltage range of the VCO is from approximately 1.5 V to 10.5 V.
Finally you will find the PLL loop filter with the two transistors Q7 and Q8, who take care of a fast locking procedure when the VCO is far off the working frequency.

Q9 and Q10 are the disabling circuit for the charge pump. The PLL is disabled during certain software routines when the DDS output is interrupted.

Interior of the DDS with PLL and VCO.

Software

Software for the AT90S1200
The crystal frequency is 11999.55 kHz. One loop of the DDS routine is 13 cycles, giving a clock frequency of 923.04225 kHz.
The DDS Accumulator Register is 4 bytes long: 256*256*256*256 = 4294967296. The Frequency Tuning Word is also 4 bytes.
The output frequency of the DDS is (923.04225 kHz * Frequency Tuning Word) / 4294967296, the PLL frequency is 128x higher
The value of the Frequency Tuning Word is changed by pressing the up-down buttons.

The trick is that changing the Frequency Tuning Word with a value of 36352 causes a frequency change of exactly 1 kHz and that 36352 is 64x568. The smallest step used is therefore 568, giving 15.625 Hz frequency variation.
If the Frequency Tuning Word is changed, the decimal digits of the display are changed accordingly. There is one register reserved for each decimal digit of the frequency. However, the lowest byte of that register is not a 0 to 9

counter but a 0 to 64 counter. If the lowest byte exceeds 63 or is lower than 0, all other decimal values are adjusted. This method was designed as all routines have to be an exact number of machine cycles, independent of what is happening. If a button is pressed, the DDS clock is 1/8 of its normal clock speed of 923 kHz and the Frequency Tuning Word is multiplied by 8.
However, it was very difficult to count all the machine cycles exactly so in the end I corrected the exact length of the various routines by measuring the pulses of the charge pump with an oscilloscope, listening to the output signal with a receiver and corrected various delays for best performance.
One NOP instruction too much or less is disastrous!

A frequency offset is programmed by setting (programming) initial values to the Frequency Tuning Word and the decimal digit registers.

Click this link to Download the Software for the AT90S1200: ["04dds1soft.zip" with the .ASM files needed to program the AT90S1200]

Results

DDS used as 5 to 5.5 MHz VFO for an old TS520.
Stability is good enough now for PSK31!

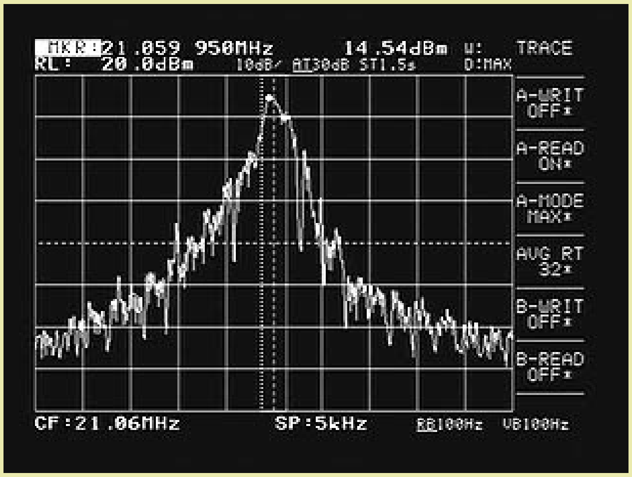
DDS used as VFO for a simple Direct Conversion receiver
that is connected to the soundcard of the PC.

5 to 5.5 MHz VFO for a TS520
An extra switch is added later to switch a capacitor of 120 pF in parallel to the varicap of the VCO to make it suitable for use as a 5 to 5.5 MHz VFO. I use it together with an old TS520SE, stability is better than the internal VFO, good enough for PSK31.

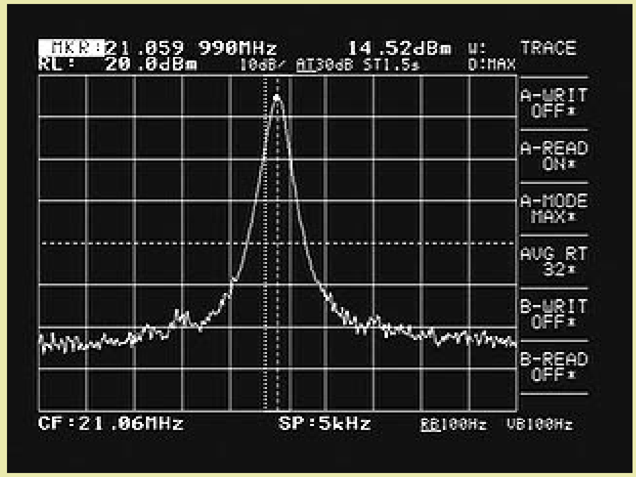
VFO for a simple Direct Conversion receiver
The DDS PLL is used as VFO for a simple Direct Conversion receiver that is connected to the Soundcard of the PC. Stability is perfect for decoding various digital signals with free available PC programs. Due to disabling the PLL during the software routines when the clock speed is lowered, the PLL can work with high DDS output frequencies without being disturbed.
There are almost no spurious signals within the audio band. If so, tune 30 Hz up or down and they are gone.
Using a microcontroller as a DDS is a very interesting idea, good for a lot of experiments in the future. I am sure than you will hear more about it from Ton and other enthousiast amateurs.

The original DDS of Ton, PA0KLT
The original DDS of Ton, PA0KLT has a D/A converter with 8 bits and a sine output, the clock frequency is higher and another PLL system is used. Tuning is done with a comfortable rotary encoder instead of 3 pushbuttons and he has implemented features to set the minimum and maximum frequency, it has a frequency memory and the tuning speeds are fully programmable. The microcontroller in his DDS is an AT90S2313 with more capabilities than the

AT90S1200 in my DDS.
Another advantage is that his DDS runs at half the clock speed during tuning and not at 1/8x during software routines.



RF signal without disabling the PLL during software routines when running 1/8 of the normal clock speed.



And here with disabling the PLL for 255 us!

BACK TO INDEX PA2OHH

ARDUINO project

AD9850 DDS based Antenna Tuner Adjustment Aid

If you use a manual antenna tuner to match your transmitter to the antenna, not causing QRM while your making the adjustments can be an issue.. This project eliminates that problem by using a very low level signal and a very sensitive SWR bridge.

An inexpensive Arduino board is use to control a AD9850 DDS module and LCD display, while a handful of discrete parts comprise the SWR bridge. A simple LED is used as the match indicator.

Operation:

It is very simple.

A preprogrammed frequency for each of the HF bands, 160 to 10 meters is selected by repetitively pushing the [CHANGE BAND] switch. I programmed in the various QRP calling frequencies in the CW segment of each band. You can of course change that in the Sketch by changing the frequency (freq) in the band look up table.

The operating frequency can be changed using a rotary encode with Gray code output. If the frequency changes in X2 steps, you have an encoder with quadature output.

The default tuning rate is 10 kHz, which allows for quickly moving the frequency to another part of the band. The tuning rate can be changed by pushing the [CHANGE RATE] button. 10 Hz, 100 Hz, 1 kHz and 10 kHz rates can be selected. The active decade for tuning is indicated by the cursor underscore of the selected decade.

Note that tuning limits are enabled so you can't tune outside of the selected Ham band.

Once the desired band and frequency is selected, the [TRANSMIT] toggle switch is used to turn the DDS signal on and off. .

When the [TRANSMIT] switch is closed, the DDS is loaded with the frequency data, a 600 Hz sidetone is generated and Pin 8 is set HIGH, which can be used to control a power amplifier or switch over relay. When the [TRANSMIT] switch is open, it loads 0 Hz into the DDS chip, effectively turning it off. You don't want to leave it on or there will be a birdie at that frequency in your receiver.

You will of course need a coax switch (or relay) to switch the antenna tuner between this device and your rig.

With the tuning aid connected to your tuner, adjust the tuner to make the indicator LED go out or to dim as much as possible.

Theory of operation:

The SWR bridge and indicator:

The SWR bridge is a Whetstone configuration, with the antenna in the unknown leg of the bridge. If the resistance of each leg is equal, there is no voltage difference between the center of the two legs, which indicates a match. I used 51 ohm resistors in the bridge as their close enough to 50 ohms, but if you do want an exact 50 ohm match, use 100 ohm resistors in parallel instead.

The bridge is driven by the square wave output of the AD9850, through a simple L/C low pass filter to remove most of the harmonics. With out this filter, harmonic from the square wave drive will reflect back and keep the LED from going completely out or at least get very dim. The filter starts to roll off at about 2 MHz so there is still enough harmonic energy when operating below 30 meters and the best you can do is make the LED very dim. You can still achive a 1:1 match without using the low pass filter, but the dip is much harder to see.

If the resistance of the unknown leg is not equal to the value of the other three resistors in the bridge, there is a voltage difference between the centers of each leg. This voltage is coupled to a high gain darlington amplifier using a step up transformer. R1 and R2 supply just enough voltage bias to the base of Q1 to improve the sensitivity without actually turning it on. A LED in series with Q2 which provides a visual indication of the amount of current flowing into the amplifier. The greater the imbalance of the bridge, the greater the voltage inputted to the amplifier and the greater the current in the collector path. The is only one potential problem with this method. If you live near a AM broadcast station you might pick up enough signal to keep the LED on all the time as you won't be able to balance the bridge at that frequency.

Construction:

I intially used a UNO R3 board for develpoment, but used a NANO board for the final assembly. The schematic show wiring for the NANO board. Because the AD9850 and the LED back lighting of the display use a fair amount of current, a seperate 5V regulator is used to power these devices, rather then using the 5V regulator on the NANO board, as it would likely get very hot.

There are two types of AD9850 DDS modules available from China. I used the one with the two rows of 20 header pins and looks like a large DIP IC. If you use the other flavor, just follow the hook up diagram to connect to the required pins. These DDS modules are running about $10 at the time of this writing. Pretty amazing since the AD9850 chip costs $21 if you bought it all by it's self.

The LCD is a common 2 line, 16 character display. The ones with blue back lighting are very common and inexpensive. These run about $3.

All three of these major components can be obtained inexpensively direct for China buying with ebay. It just takes a few weeks to get them. If your in more of a rush, banggood.com can ship these from a US warehouse for a small price premium.

The rest of the discrete parts needed to build the SWR bridge and indicator can be obtained for the usual sources like Mouser or Jamesco. The MSP5179 transistors have a 1 GHz hft, so they still have decent gain at 28 MHz. You could sub the more common 2N3904's but it won't be as sensitive on the higher bands or may not work at all. If the LED does not light or is very dim at the higher frequencies, you don't have enough gain.

Since most of the componets are modules, I buit the project on a piece of FR4 pref board, using SIP sockets for the modules to plug into. The SIP sockets come in 40 pin strips. To cut them down to size, remove the pin one location past the number of pins you need and cut that slot with an hobby knife of razor saw. I use #28 heat stripable magnet wire to make all the interconnections. That way I don't need to strip insulated wire and makes for a neat looking wiring job.

The SWR bridge and amplifier could have been wired up right on the perf board, but I built it on a small scrap of copper clad board, dead bug style, which is a bit quicker and easier way to build it.

For final packaging, I recycled an old Radio Shack enclosure. Since the front panel of this box already had a number of holes in it (all in the wrong places, except for the display window, which was cut for a smaller display) I had to cover the old holes up somehow. I did this by simply putting down some double sided tape on the panel and then laid down a piece of black contruction paper and trimmed it to fit. This is then covered with a thin piece of clear Polycarbonate, which is easy to work with.

Programming the Arduino and the program "Sketch":

Hopefully your already familiar with the Arduino. If not a simple web search will come up with linksto the official Arduino web site with all the info you need.

The Sketch which you need is located in this zip file: Arduino_9850_sketch.zip

Once the Sketch has been downloaded into the Arduino board and everything is wired up, you will have to make one adjustment on the DDS module board. With the "unknown" leg of the bridge open, adjust the little trimmer resistor on the 9850 module until the SWR indicator LED comes on brightly. This trimmer sets the duty cycle of the square wave output and you want it more or less centered at 50%, but without a 'Scope just set it in about the middle of the adjustment range which makes the SWR LED stay on.

Parting thoughts:

This is my first Arduino "Sketch" and I'm pretty amazed I was able get it to work. I did take some late nights just to figure out how to do some simple things. I normally program directly in assembly which makes a whole lot more sense to me and is vasty more memory efficient and faster.

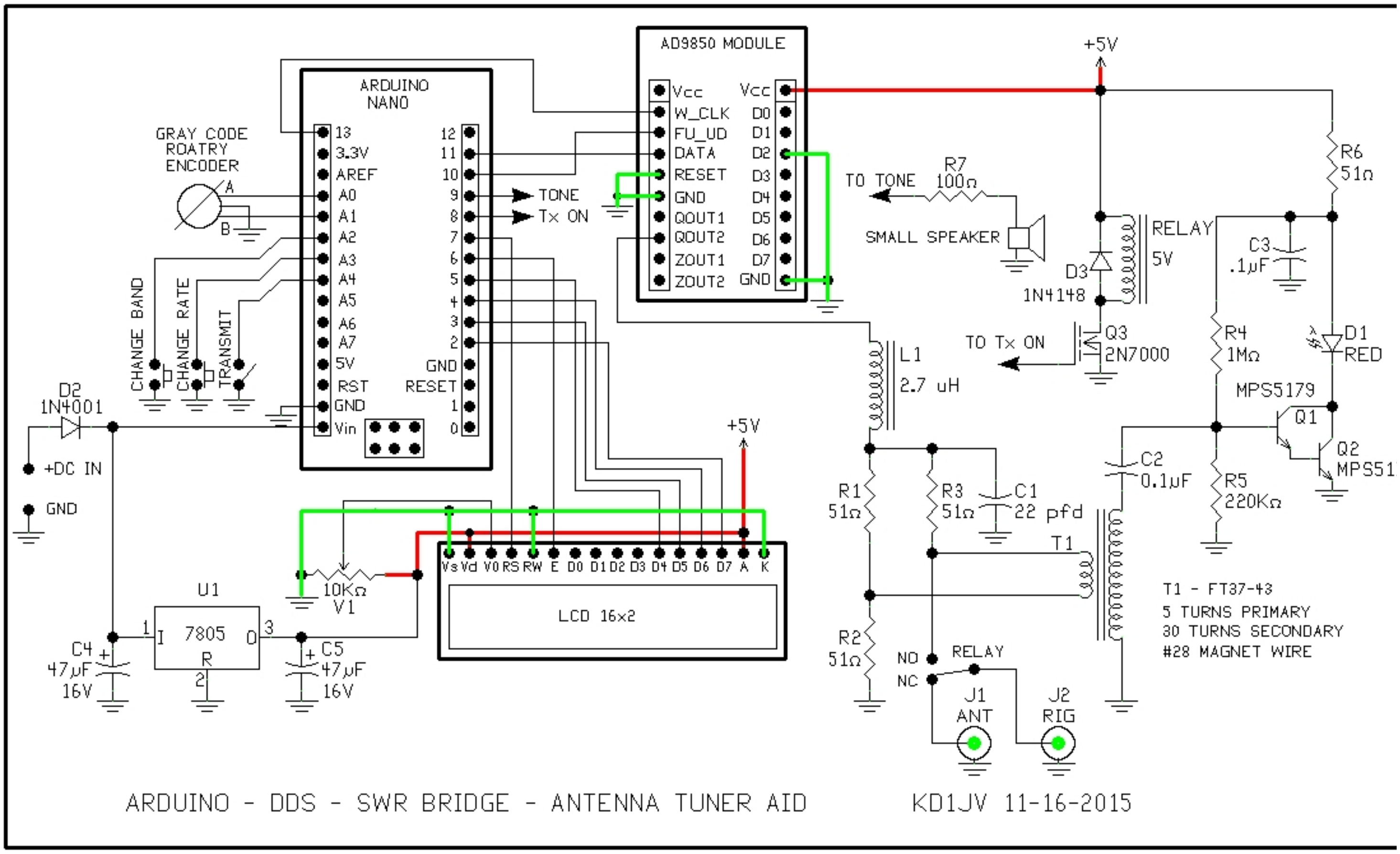
Although I designed this for the SWR bridge application, it can also be used as a signal generator, a transmitter VFO or even the VFO for a transceiver, although some modifications to the Sketch will be required for other applications.

For use as a signal generator with full tuning range, comment out the band limit tests in the DDSincerment() and DDSdecerment() routines and enable the max freq and min freq limits instead.

For a transceiver, you can add or subtract an offset to the base frequency before loading the DDS chip.

Anyway, I hope someone finds this project useful.

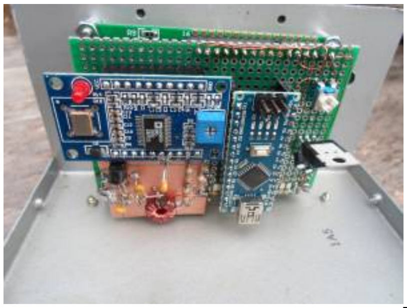
73, Steve KD1JV

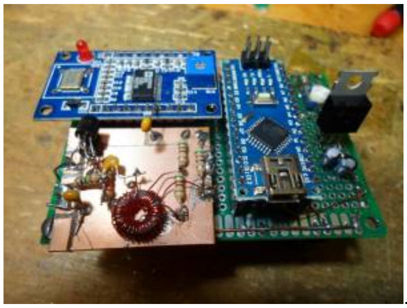
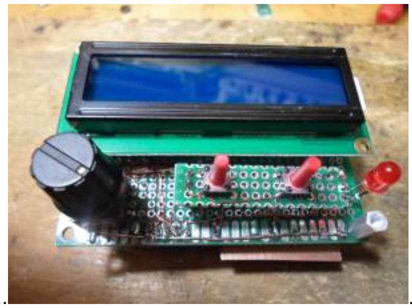


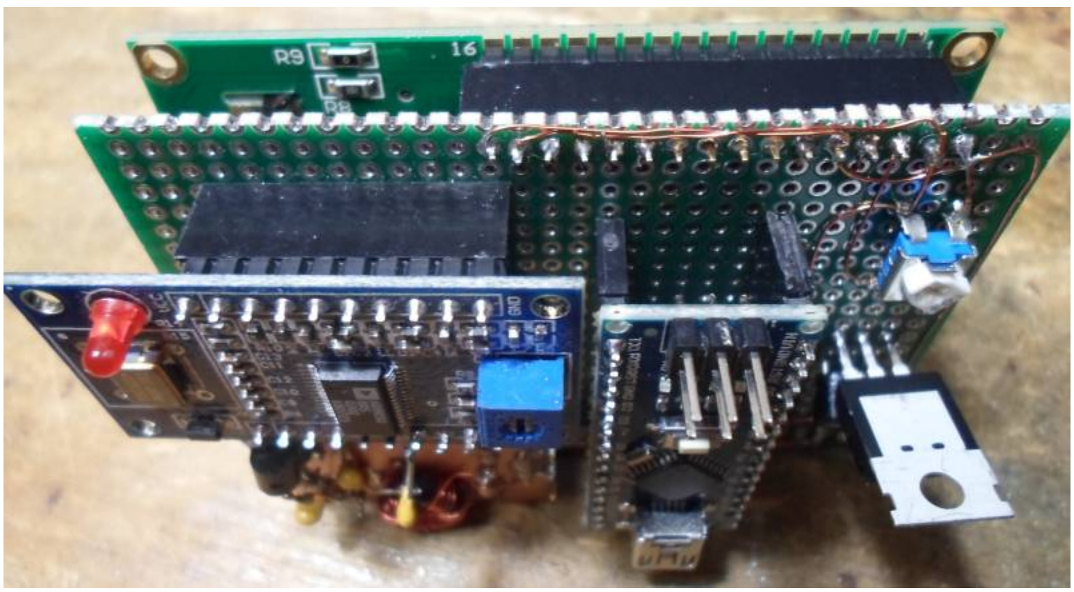
Arduino to LCD/DDS connection table.

Arduino pin	LCD pin	DDS pin
2	D7	
3	D6	
4	D5	
5	D4	
6	E	
7	RS	
8		
9		
10		FU_UD
11		DATA
12		
13		W_CLK


__Inside front panel showing the old holes which needed to be covererd up.

_-board assembly mounted to the front panel.

....Front and back views of board assembly. I should have spaced the encoder higher off the main board so the knob would have stuck out the front panel a bit farther...



an electronic project to construct an LC meter project kit of exceptional accuracy to measure both inductance and capacitance - an inductance meter and capacitance meter all in one unit. It also is readily available as a comparatively inexpensive kit which is sure to prove a boon for the average home constructor

Ian Purdie's Amateur Radio Tutorial Pages

[you can have this page translated /vous pouvez faire traduire ces pages /Sie können lassen diese Seiten übersetzen /potete fare queste tradurre pagine /você pode ter estas páginas traduzido /usted puede hacer estas paginaciones traducir]

LC METER PROJECT AND KIT - L/C Meter IIB

a project designed and written exclusively by NEIL HECKT of Almost All Digital Electronics

BACK TO HOME PAGE

Foreward by Ian C. Purdie

When this electronc project first appeared in the American magazine **ELECTRONICS NOW** back in July 1998 I was somewhat initially amazed by the claims made for its performance.

As it subsequently happened some months later, I had an opportunity to purchase a complete kit for myself from Neil when a member of my family visited the U.S.A.

I found the instructions quite easy to follow and yet although I am an experienced constructor, albeit suffering from diminished eyesight, I found that even I could easily have this kit up and running as was claimed within a couple of hours. Although I must mention I did take time out for several cups of coffee.

I found all the claims made about the project and the kit were perfectly true. If you really want a first class piece of test equipment to measure inductance or capacitance then this project is really for you.

Neil is quite happy for anyone to build it themselves using their own source of parts but really why would you bother when you can obtain the pcb and everything else so conveniently at one place and directly from the author himself?

Currently this very handy electronic project comes in complete kit form for the economical price of $US 99.95 + s/h.

If you're not especially confident of your construction skills or you simply don't have the time, then Neil will supply a ready built and tested unit for only $US129.95 + s/h. Commercially made units cost a great many more times than that amount.

On behalf of all, I would personally like to thank Neil for sharing his LC Meter project with us, I think he has been most generous. Also I think you will find the underlying principle of Neil's design to be rather ingenious, I most certainly did. May Neil continue to enjoy the success that he so richly deserves.

Read on and enjoy this unique project as much as I did myself.

Ian C. Purdie 12th April, 2000

Disclaimer - apart from being a satisfied user I have no commercial relationship whatsoever with Almost All Digital Electronics (AADE) and I have paid the full advertised price for my LC Meter kit.

Any advertising benefit which might be derived by AADE on this page is by way of compensation for presenting an interesting electronic project for our mutual benefit and enjoyment. The links to AADE are provided to assist my readers.

TABLE OF CONTENTS FOR LC METER PROJECT

Specifications

RANGE
.001 mH (1 nH) to 100 mH (most units measure to 150 mH)
.010 pF to 1 mFd (most units measure to 1.5 uF)
(capacitors must be non-polarized)

AUTOMATIC RANGING
Accuracy:
1% of reading Typical

Typical means the average error of 83 different components compared to an
· HP4275A digital L/C meter (test frequency 1MHz) for components ranging from .1uH to 1mH and 2.7pf to .068uF,
· B&K 878 digital LCR meter (test frequency 1KHz) for components ranging from 1mH to 100mH and .1uF to 1.6uF.

View the table of data upon which these claims are based

SELF CALIBRATING

DISPLAY
16 Char intelligent LCD
Four Digit Resolution
Direct display in engineering units, ie: Lx= 1.234 mH / Cx= 123.4 pF

Sampling Rate:
Approximately 5 samples / second. (will track while adjusting adjustable components)

The unit displays values in one of two modes which can be changed during operation. The "micro mode" displays values in uH, mH, pF, and uF when applicable. In this mode, for example, 10.00 nano-Farads displays as .01000 micro-Farads and 1 nano-Henry displays as .001 micro-H. It is for old timers like me and is the way many parts are marked. The "nano mode" is for those more metrically inclined. Table 1 shows how each range is displayed in each mode.

INDUCTANCE nano mode	INDUCTANCE micro mode	CAPACITANCE nano mode	CAPACITANCE micro mode
000-999 nH	0.000 - 0.999 uH	0.00 - 0.99 pF	0.00 - 0.99 pF
1.000 - 9.999 uH	1.000 - 9.999 uH	1.00 - 9.99 pF	1.00 - 9.99 pF
10.00 - 99.99 uH	10.00 - 99.99 uH	10.00 - 99.99 pF	10.00 - 99.99 pF
100.0 - 999.9 uH	100.0 - 999.9 uH	100.0 - 999.9 pF	100.0 - 999.9 pF
1.000 - 1.999 mH	1.000 - 1.999 mH	1.000 - 9.999 nF	1000 - 9999 pF
10.00 - 99.99mH	10.00 - 99.99mH	10.00 - 99.99 nF	.01000 - .09999 mF
100.0 - 999.9 mH *	100.0 - 999.9 mH *	100.0 - 999.9 nF	.1000 - .9999 mF
		1.000 - 9.999 uF *	1.000 - 9.999 uF *

TABLE 1. Display Options (* Some values out of range)

One input pin to the micro controller is a jumper which determines if the unit powers up in the "micro mode" (jumper open) or "nano mode" (jumper shorted).

Operating Modes

When the Lx and Cx switches are off pressing the ZERO button sequences L/C Meter IIB through five different operating modes.

READY MEASURE n measures Lx or Cx and displays the result in "nano mode" ie: Lx = 99 nH, Cx = 12.34 nF

READY MEASURE u measures Lx or Cx and displays the result in "micro mode"
id: Lx = .099 uH, Cx = .01234 uF

READY MATCHnMODE first measures a reference component Lz or Cz and displays the value in "nano mode". When the ZERO button is pressed this value is stored in RAM and the difference between it and subsequent components is displayed in "nano mode"
ie: Lx - Lz = 99 nH, Cx - Cz = 12.34 nF

READY MATCHuMODE first measures a reference component Lz or Cz and displays the value in "micro mode". When the ZERO button is pressed this value is stored in RAM and the difference between it and subsequent components is displayed in "micro mode"
ie: Lx - Lz = .099 uH, Cx - Cz = .01234 uF

READY MATCH%MODE first measures a reference component Lz or Cz and displays the value in "nano mode". When the ZERO button is pressed this value is stored in RAM and the ratio of the difference between it and subsequent components is displayed in percent.
ie: (Lx - Lz)/Lz*100 =12.34%, (Cx - Cz)/Cz*100 = 12.34%

Note that a positive reading in the matching modes means Lx is greater than Lz or Cx is greater than Cz and visa versa.

L/C Meter II is intended to measure inductors and capacitors "out of the circuit". Inductors must have a reasonable Q for their value and negligible distributed capacitance for their value. I have tested it using commercially available RF chokes ranging from 0.1 micro-Henry to 1000 mico-Henry , Hash chokes up to 100 mico-Henry wound on ferrite rods, on Pi-wound RF chokes up to 7.5 milli-Henry, on toroid wound inductors up to 150 milli-Henry (such as the HI-Q series obtainable from Mouser Electronics), and on several slug tuned inductors from a Coilcraft Slot-10 designers kit (similar to the TOKO line of tunable inductors).

Circuit Description

The Oscillator

The key to L/C Meter IIB's operation is the oscillator circuit of FIGURE 1. The LM311 is a voltage comparator. When power is applied, the voltage at pin 2 is 2.5 volts causing the output to be at a level of 5 volts. This charges capacitor C4 through resistor R4 until the voltage at pin 3 equals 2.5 volts. As it reaches 2.5 volts the output switches to a low level inducing a transient into the tank circuit composed of L1 and C1. The transient causes the turned circuit to ring at it's resonant frequency. The ringing causes a square wave at the resonant frequency to appear at the output of the voltage comparitor. The square wave is coupled back to the tuned circuit through R3 and C3 sustaining oscillation.

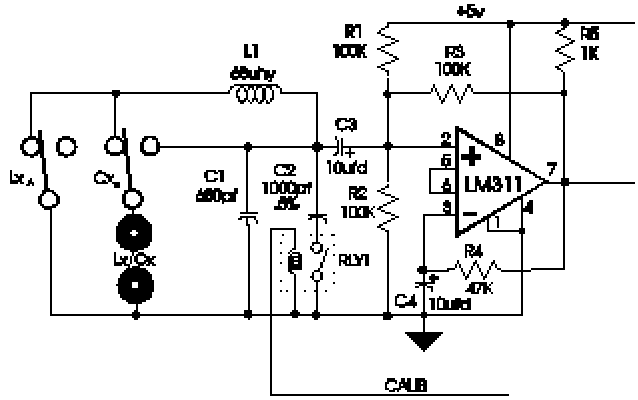


FIGURE 1 OSCILLATOR

For the nominal values of L1 (68 uH) and C1 (680 pF) an increase in L of 1 nH (.001 uH) or an increase in C of .01 pF produces a frequency change of slightly more than 5 Hz. A 0.2 second measuring period can resolve 5 Hz and therefore .001 uH or .01 pF.

Besides being simple, this oscillator circuit is very reliable in that it always starts and can tolerate a large variation in the inductance and capacitance used in the tank circuit.

The Micro-computer

The complete schematic is shown in FIGURE 2. The output of the oscillator is applied to the RTCC, Real Time Clock Counter, pin. This increments an 8 bit counter inside the micro-computer. The micro-computer accumulates the count for a period of 0.4 seconds. The frequency is then the accumulated count divided by the period. Discrete signals from the Lx, Cx and ZERO switches are input to the micro-computer so it knows what the operator wishes it to do.

Self-Calibrating

During the calibrate cycle the micro-computer first measures F1, the frequency when only L1 and C1 are in the tank circuit. The frequency will be:

$$F1 = \frac{1}{2\pi\sqrt{L1\,C1}}$$

In order to obtain another equation, so that we can solve for both L1 and C1, a known capacitor is switched into the tank circuit. The micro-computer energizes relay RLY1 by raising the CALIB line to a logic high level which switches capacitor C2 into the tank circuit. C2 is a 0.5% tolerance 1020 pF capacitor composed of C2a and C2b. C2a is a 1000pf 2% polystyrene capacitor. C2b is an NPO ceramic which in parallel with C2a is 1020pf +/-5pf. This causes the frequency to become:

$$F2 = \frac{1}{2\pi\sqrt{L1\,(C1 + 1020)}}$$

The two equations can be solved simultaneously to give:

$$C1 = \frac{F2^2}{(F1^2 - F2^2)}\ 1020\ \text{pF}$$

and finally:

$$L1 = \frac{1}{4\pi^2 F1^2\, C1}$$

Because of this self-calibration capability, the exact values of L1 and C1 are not critical and 10% tolerance components are used. The accuracy of the device is dependent upon C2 which is a .5% tolerance capacitor combination.

Measuring Inductance and Capacitance

When the Lx and Cx switches are off the micro-computer continuously measures F1 to track any drift in frequency. When the Lx switch is depressed the unknown inductor is placed in series with L1. The total inductance is then L1 + Lx. This causes the frequency to change to:

$$F2 = \frac{1}{2\pi\sqrt{(L1 + Lx)\,C1}}$$

This equation can be solved, simultaneously with the equation for F1:

$$F1 = \frac{1}{2\pi\sqrt{L1\,C1}}$$

to produce:

$$Lx = \left[\frac{F1^2}{F2^2} - 1\right] L1$$

Similarly when the Cx switch is depressed the unknown capacitor is placed in parallel with C1. The total capacitance is then C1 + Cx.

$$F2 = \frac{1}{2\pi\sqrt{L1\,(C1 + Cx)}}$$

Which is solved for Cx, with the equation for F1, to produce:

$$Cx = \left[\frac{F1^2}{F2^2} - 1\right] C1$$

Stray Inductance and Capacitance

The circuit traces on the PCB, the switches , and the test leads all contribute a small amount of "Stray" inductance (Ls) and capacitance (Cs). These stray values add to the values of Lx or Cx. The unit is zeroed by pressing the ZERO switch which causes the unit to store the values of stray inductance or capacitance and subtracts them from the measured values. The values displayed are thus:

$$Lx = \left[\frac{F1^2}{F2^2} - 1\right] L1 - Ls$$

and:

$$Cx = \left[\frac{F1^2}{F2^2} - 1\right] C1 - Cs$$

To zero Ls the operator must short circuit the test leads, press Lx and then press the ZERO button. Similarly, for capacitors, the operator open circuits the test leads, presses Cx and then presses ZERO.

The stored values of Ls and Cs are saved until the operating mode is changed. When measuring components, it is not necessary to re-ZERO between components. When the operating mode is changed from MEASURE to MATCH these values are reset to zero.

You will notice from the above equations that inserting an unknown always causes F2 to be less than F1. If an inductor is inserted when the Cx switch is depressed the result will be an increase in frequency, F2 greater than F1, rather than a decrease. This is because the inductor has been placed in parallel with L1 and inductors in parallel always are less than the value of the smallest of the two values. If the unit detects an increase in frequency it will display "NOT A CAPACITOR". This does not work for very large values of Lx. The decrease in the effective value of L1 is trivial while the shunt capacitance of the large inductor is significant and the frequency will decrease causing an erroneous reading. The effect of putting a capacitor in when the Lx switch is pressed is similar except the oscillator tends to stop causing F2 to be zero. The unit detects this and displays "NOT AN INDUCTOR". This is not true for very large values of Cx in which case the unit may display an erroneous reading.

L/C Meter IIB can zero out ANY value in it's range. If a value is inserted and ZERO'd the unit will display the difference between it and subsequent components similar to the MATCHnMODE and MATCHuMODEs. The difference in the MATCHxMODEs is that the range is frozen to the resolution of the initial component. This limits the minimum difference in values to be 1 part in 10,000 or .01%. The reason for this may not be obvious. The maximum resolution of the unit is four digits **at the value of the components being measured**. Consider two components, one with an exact value of 5000 pF and the other with an exact value of 5010.25 pF. The difference would be 10.25 pF, however the unit cannot resolve less than 1 pF at this range and it would be misleading to display the fractional portion of the difference.

Construction

The unit is indeed simple and there is no particular order of assembly. Refer to parts layout, for important information.

NOTE: there is only 3/8 inch (10 mm) space under the display, leave enough lead length to tip taller parts at an angle so that the vertical dimension does not exceed 3/8 inch (10 mm).

Precision alignment of the switch pins is required for easy installation. Align the pins parallel to each other by eye-ball (particularly the two rows of pins when viewed from the rear of the switch). Start by inserting one or two rows of pins with the switch at an angle to the PCB. Turn the assembly upside-down with the switch resting on top of your bench and press down on the PCB. Do no press down on the switches as there is a risk of pushing the pins all the way out of the body of the switch.

Solder J1, the female square post header, at the top of the PCB. Solder just one pin then make sure the connector is perpendicular to the PCB then solder the rest.

Install the contrast control, R6, on the back of the PCB otherwise you will not be able to adjust it with the display installed. Install the two 3/4 inch (20 mm) spacers for the test jacks as shown in Mechanical Detail. This should complete the PCB assembly.

Decide which type of capacitor display you prefer the unit to be in upon power-up. If you prefer the nF method solder a jumper wire as indicated on the parts layout.

Pass the leads from the battery clip through one of the slots in the battery box of the case and solder them to the appropriate pads of the PCB. Plug in the display, turn the contrast control fully clockwise and turn on the unit. The unit will display "WAIT" for 10 seconds followed by "CALIBRATING" for two seconds followed by "READY MEASURE x". If so, your up and running. Adjust the contrast control so the background is just barely visible. Install the PCB in the bottom of the case using three #4 sheet metal screws. Install the top cover of the case and install the binding posts as shown in Figure 4, Mechanical Detail. Test leads should not exceed 4 inches (100 mm) in length with a banana plug at one end and alligator clip at the other.

It may be necessary to "move" the edge of a hole or slot in the case. This is easily done using sandpaper, file or hobby knife. Before fitting the test jacks or screws in the back of the case, fit the cover and squeeze the case together while testing the switches for binding to the edge of the slot. "Move" the edge as required.

Troubleshooting

It is very unlikely you will have any problems, however, if you just can't seem to get it to work I will try to fix it free except for a $US4.00 return postage and handling fee.

If it did not work, remove the PCB and carefully inspect to see you have soldered everything that should be soldered and have not soldered anything that should not be (look for solder bridges). Bad soldering accounts for 99% of units failing to work immediately. Here are some hints on where to look.

1) **Blank display**, contrast control not adjusted correctly. Start with it fully clockwise.

2) **Blank display**, check 5V power to CPU and display.

3) **Displays 8 black squares**, CPU not communicating with display. Check solder around CPU and display. CPU crystal not oscillating. Check with oscilloscope if possible.

4) **Displays WAIT, then CALIBRATING and sticks in CALIBRATING**. **A)** Oscillator (LM311) is not oscillating. Check soldering around LM311, LM311 properly installed, parts properly installed. C3 in backwards?. **B)** ZERO button stuck in or not soldered. Check continuity to ground from pin 13 of the CPU.

5) **Seems to work but readings appear way off from components marked value**. Calibration capacitor not correctly installed or relay in backwards. (relay should be installed with it's part number opposite the switches (facing the LM311) and little circle toward top of PCB).

Operation

The typical stray inductance is .04 to .06 m H's and the typical stray capacitance is 5 to 7 pF's. When measuring inductors less than 5 m H's or capacitance's less than 50 pF's it is advisable to ZERO the unit first. For larger values the strays are insignificant to the result. It is difficult to retain a reading of 0.000 pF's because of the extreme sensitivity of the unit. Your body capacitance influences the reading. Try ZEROing the capacitance and then move your hands around the test leads without touching them. You will find your can adjust the reading a few hundredths of a pF.

To measure inductance place the unknown across the test leads and depress Lx. To measure capacitance place the unknown across the test leads and press Cx.

The oscillator tends to drift a few Hertz during the first few minutes of operation. When measuring very small values the unit should be allowed to warm up for about five minutes. With a resolution of 5 Hz, thermal drift will always occur as evidenced by a slowly drifting reading. The first readings after pressing Lx or Cx are the most accurate.

Accuracy and Resolution

L/C Meter IIB is specified at 1% of reading. I have about 60 components which I had measured on a HP4275A L/C meter. Measuring these components on L/C Meter IIB found an average error of 0.23% for inductors and 0.24% for capacitors. These values ranged from .1 mH to 6.8 mH and 2.7pF to .068 mF. These measurement were for a single unit and could vary, from unit to unit, by .5% as a function of the exact value of C2.

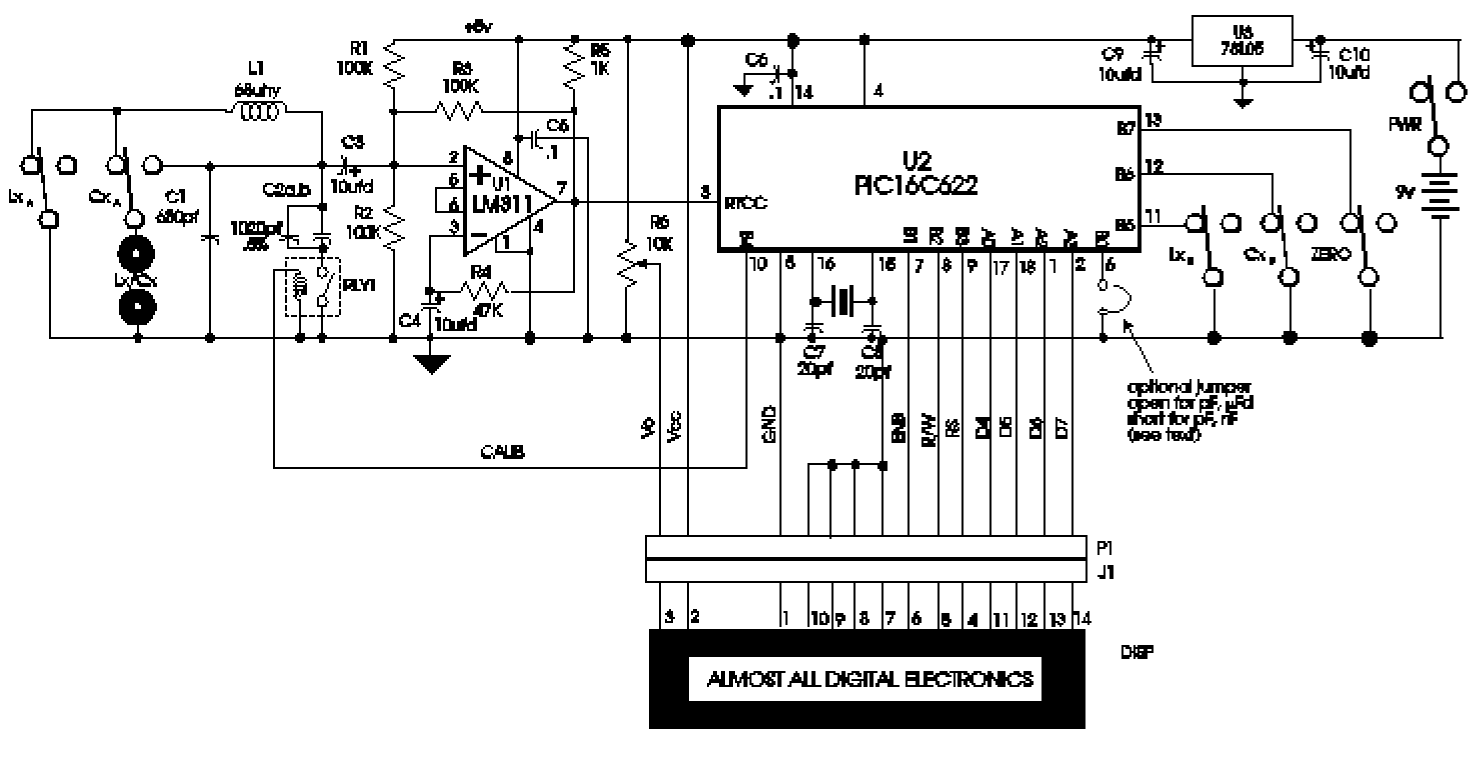
L/C Meter IIB has four digit resolution which for small values of L and C are 1 nH and .01 pF. You cannot accurately measure values this small. The resolution greatly exceeds the accuracy. You can measure values as small as .01 mH and .1 pF with about 15% accuracy. You generally won't find components this small. For example a piece of wire less than one inch long is .01 m H. The resolution is, however, relative and can be used for sorting a batch of similar components as it truly does indicate which are slightly larger of smaller than others. Also, for small values of inductance, the leads will contribute quite a bit to the value. Measuring from the ends of the leads instead of next to the body of the component can add up to .025 mH.

For small values the frequency of operation (test frequency) is about 750 KHz decreasing to about 60 KHz at .1 m F's or 10 mH's and about 20 KHz at 1 m F or 100 mH's.

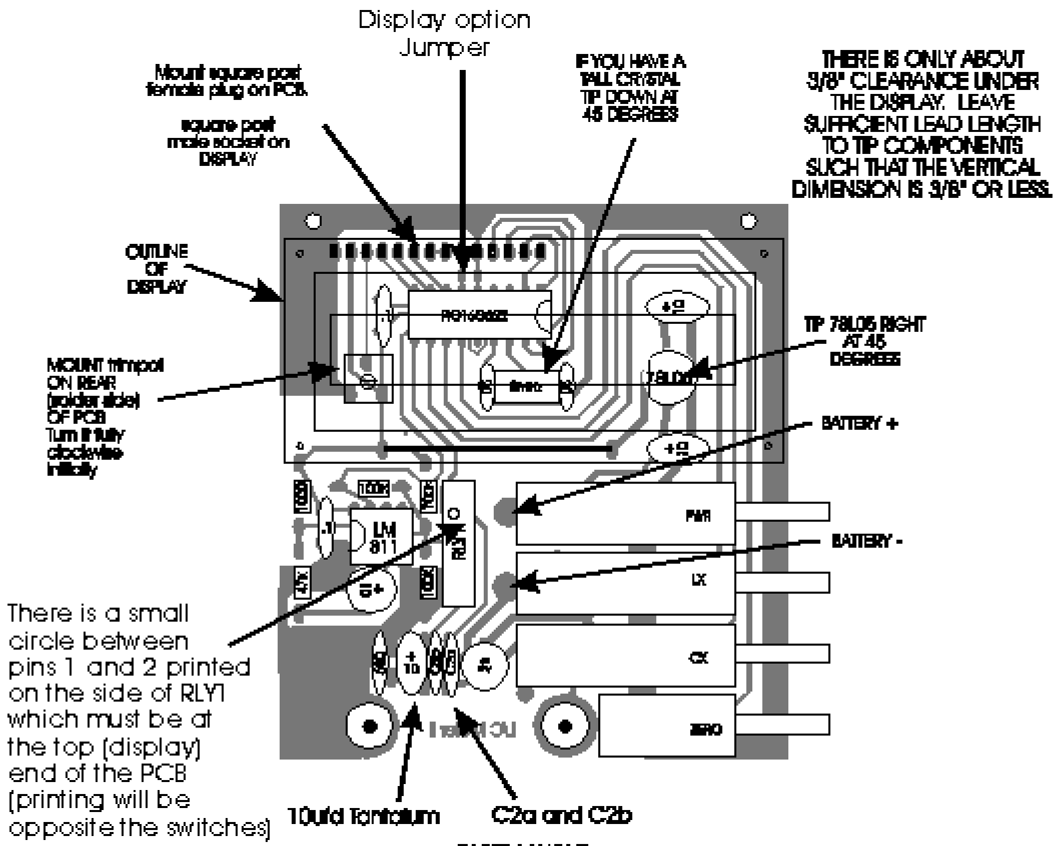
Parts List

R1, R2, R3	100K ohm 1/4 watt
R4	47K ohm 1/4 watt
R5	1000 ohm 1/4 watt
R6	10K ohm potentiometer
C1	680pF **(disc ceramic marked 681 500v)**
C2a	1000pf 2% **(C2a and b are packed in a little brown envelope)**
C2b	5, 10, 15, 20, 24, 27, 33, or 39pf NPO
	as required to make 1020pf total.
C5,C6	.1 m F ceramic **(tan monolythic marked 104)**
C3	10 m F /10v Tantalum **(tan tear drop shaped, observe polarity)**
C4,C9,C10	10 m F /10v electrolytic **(black radial, observe polarity)**
C7,C8	22 pf ceramic **(brown disc marked 22J)**
X1	8.0 MHz crystal
L1	68 m H **(blue)**
U1	LM311N voltage comparitor
U2	PIC16C622 microcomputer
U3	78L05 voltage regulator
RLY1	SPST N.O. reed relay **(has diode, observe install orientation)**
DISP	LM-16151 or equiv'
J1	14 pin square post socket **(built onto the display module)**
P1	14 pin square post plug **(install on PCB)**
Lx, Cx, PWR	DPDT alternate action SW
ZERO	DPDT momentary SW
Test Jacks	5 way binding posts

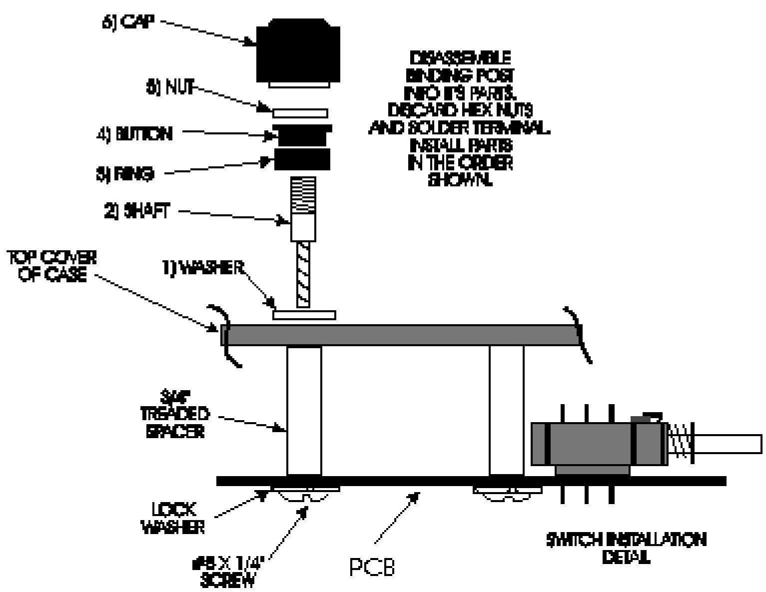
Schematic Diagram



L/C METER IIB SCHEMATIC



PARTS LAYOUT



MECHANICAL DETAIL

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Auburn, WA 98092

TECHNICAL SUPPORT

Voice 253-351-9316
9 a.m. - 9 p.m. (usually available on weekends)

FAX 253-931-1940

e-mail **neil@aade.com**

Visit our web site at:

http://www.aade.com

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Send Check, Money Order or call / FAX with Visa / MasterCard

Call between 9 a.m. - 9 p.m. - Pacific time, 7 days

Almost All Digital Electronics, 1412 Elm St. S.E., Auburn, WA 98092 U.S.A.

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Feedback

Consider joining our friendly Electronics and Answer Email List to **get your questions answered** in a friendly way. No College or High School assignments though! To give me feedback, comments, suggestions use this **friendly contact form** this on site.

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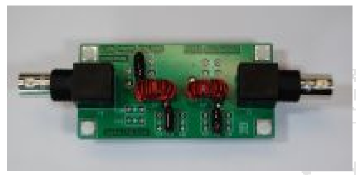
Easy Receiver

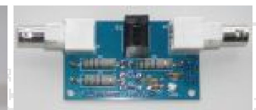

Easy Transmitter


Easy Audio Bandpass Filter


Easy TR Switch


Easy Field Strength Indicator


Easy Low Pass Filter


Easy SWR Indicator

Easy Receiver

Features

- Easy to build and use.
- No toroids to wind and only one adjustment to set the receive frequency.
- Assembles in 1-2 hours.
- Covers approximately 75kHz of the 40M band.
- Direct conversion design with a bandpass filter, NE602 mixer and LM386 audio amplifier.
- Mates with our Easy Transmitter and Easy Audio Filter to make a QRP station.

Manuals and other useful information

Easy Receiver for 40 Meters ver (5/27/2017)

Ordering Information

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Easy Receiver Kit: $25.00

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Easy Transmitter

Features

- VXO tuning range of approximately 1KHz on 40M
- Choice of 7.030 or 7.040 crystal
- Powered from 9-15V
- Output of approximately 2 W Designed for use with our Easy RX and Easy Bandpass Filter Kits
- Fun kit to build for anyone wanting a basic transmitter kit
- No toroids or coils to wind
- Can be built in 1-2 hours or less
- A great kit for new builders and club or group builds

Manuals and other useful information

Easy Transmitter for 40 Meters ver (11/08/2017)

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Easy Transmitter Kit 40M (7.030 Crystal): $25.00

Easy Receiver/Transmitter Combo Kit 40M (7.030 Crystal): $45.00

Easy Receiver/Transmitter Combo Kit 40M (7.040 Crystal): $45.00

Easy Transmitter Kit 40M (7.040 Crystal): $25.00

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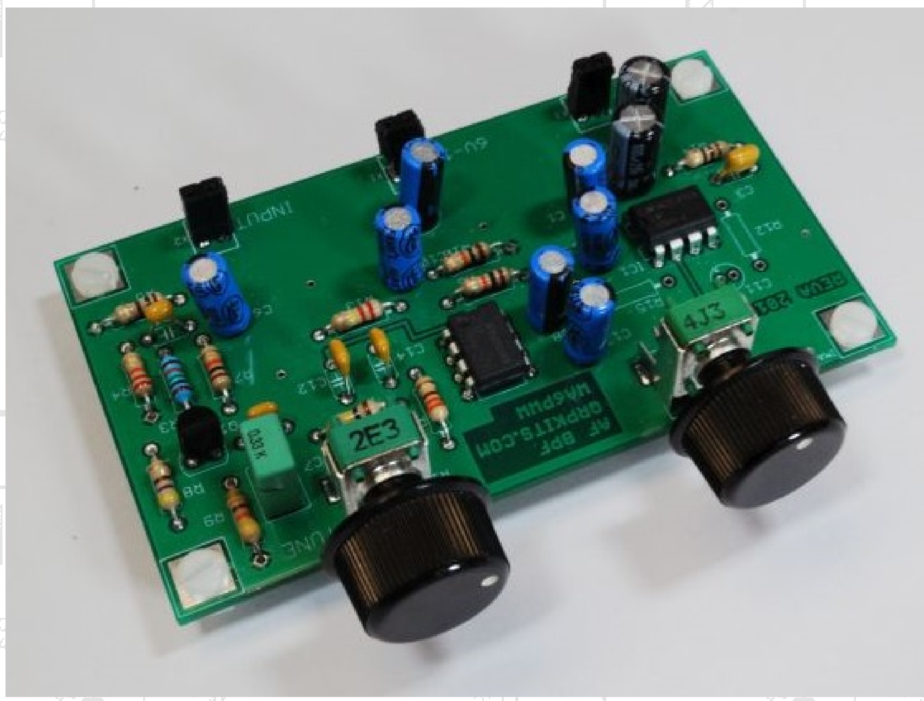
Easy Audio Bandpass Filter



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- Has a peak in response that is tunable from approximately 300Hz to 2Khz
- Tuning and volume pots for adjustment
- Build in 1-2 hours or less
- Designed for use with our Easy RX kits or other radios to add audio filtering

Manuals and other useful information

Easy Audio Bandpass Filter ver 4 (5/27/2017)

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Easy Bandpass Filter Kit: $25.00 Add

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Easy TR Switch

Features

- A simple switch to provide transmit receive switching
- Has two separate switched sets of contacts
- RF sensing built in and activates with as little as 100mW of RF
- Can be hard keyed by grounding pins on control header
- Handles 150W of RF over 160-6M

Manuals and other useful information

Easy TR Switch Ver 3 (12/12/2017) UPDATED

Easy TR Switch Ver 2 (05/23/2017)

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Easy TR Switch Kit: $20.00 Add

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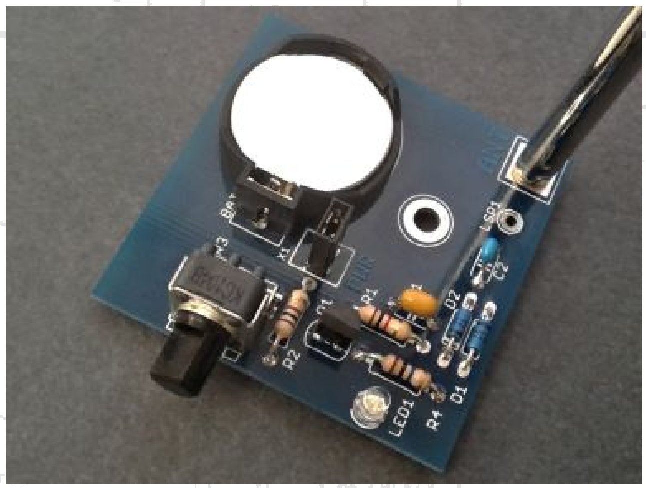
Easy Field Strength Indicator



Features

- Provides a visual monitor of RF fields through the brightness of an LED
- Responds to fields from approximately 1MHz to a few hundred MHz
- Circuit board is 1.75x1.75 inches
- Uses a high brightness LED to indicate field intensity
- Powered by a 2032 coin cell battery or external 3-9V power source
- Can be built into a housing or used stand alone

Manuals and other useful information

[Easy Field Strength Indicator Manual (12/14/2017](#) UPDATED

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Easy Field Strength Indicator: $15.00 Add

Optional whip antenna: $2.50 Add

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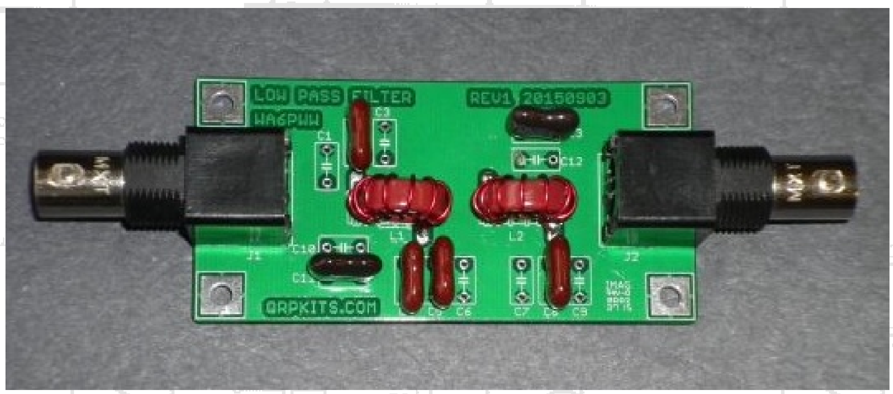
Easy Low Pass Filter



Features

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Our Easy Low Pass Filter kit from Pacific Antenna is 5 pole LC filter designed to reduce harmonics and spurious signals.

When properly configured, our low pass filter is capable of significantly reducing harmonics with minimal effect on the desired signal.

Ideal for reducing band to band interference for field day and contest stations.

This is a relatively simple kit to build and is ideal for beginners.

Specifications

- Versions available for 80, 40, 30 and 20 Meter bands
- Power handling up to 100W under matched conditions
- Reduction of harmonics by more than 50dB
- Constructed on a 1.75x 3.5 inch printed circuit board
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- Includes board mounted BNC connectors and all necessary parts

Manuals and other useful information

[Easy Low Pass Filter Assembly Manual (05/27/2017)]

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Easy Lowpass Filter 20m: $15.00 Add

Easy Lowpass Filter 30m: $15.00 Add

Easy Lowpass Filter 40m: $15.00 Add

Easy Lowpass Filter 80m: $18.00 Add

View your shopping cart: Check Out

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Easy SWR Indicator

Features

- Designed for power levels of 0.2 to 5 Watts
- Provides protection for transmitter by limiting reflected power during tuneup
- Indicates match to antenna by dimming of LED
- Constructed on a 1.5x 2.5 inch printed circuit board
- Includes board mounted BNC connectors.

Manuals and other useful information

[Easy SWR Indicator Assembly Manual (5/27/2017)]

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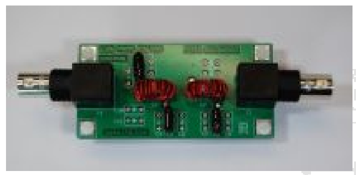
Easy Receiver


Easy Transmitter


Easy Audio Bandpass Filter


Easy TR Switch


Easy Field Strength Indicator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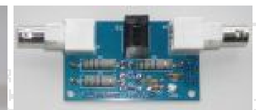
Easy SWR Indicator

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Features

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Manuals and other useful information

Easy Receiver for 40 Meters ver (5/27/2017)

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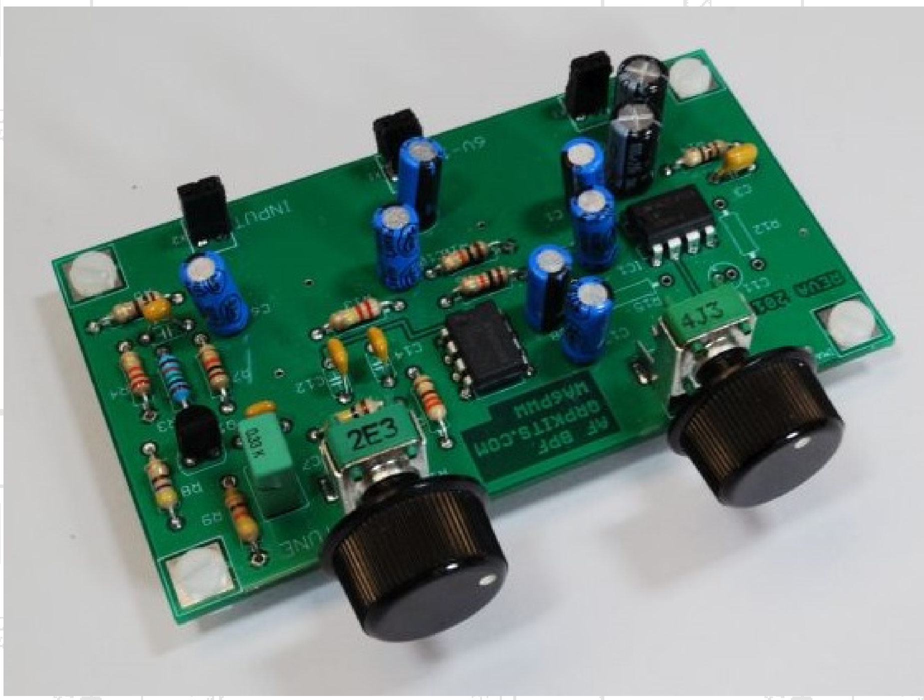
Easy Audio Bandpass Filter



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Easy Audio Bandpass Filter ver 4 (5/27/2017)

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Manuals and other useful information

Easy TR Switch Ver 3 (12/12/2017) UPDATED

Easy TR Switch Ver 2 (05/23/2017)

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Easy TR Switch Kit: $20.00

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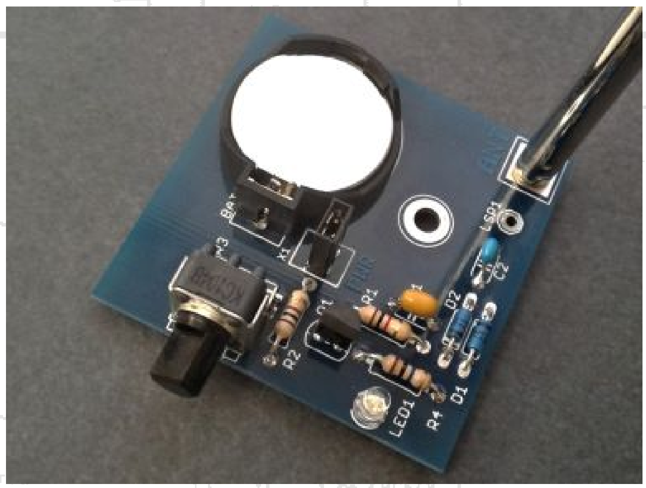
Easy Field Strength Indicator



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Manuals and other useful information

Easy Field Strength Indicator Manual (12/14/2017 UPDATED

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Easy Field Strength Indicator: $15.00	Add
Optional whip antenna: $2.50	Add
View your shopping cart:	Check Out

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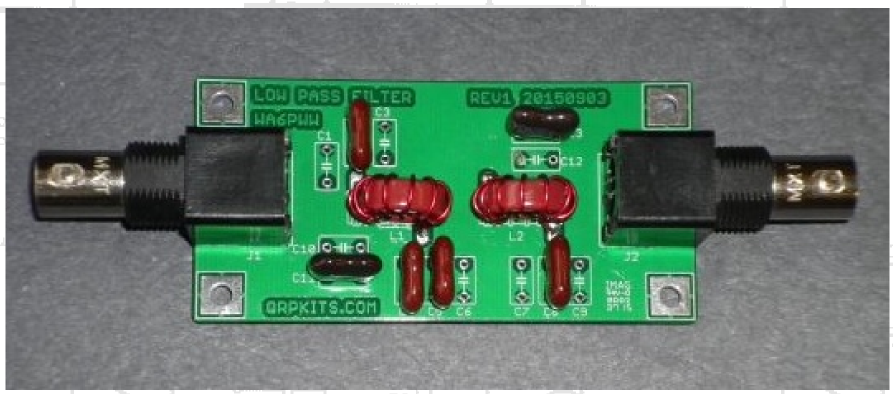
Easy Low Pass Filter



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Manuals and other useful information

[Easy Low Pass Filter Assembly Manual (05/27/2017)](#)

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- Constructed on a 1.5x 2.5 inch printed circuit board
- Includes board mounted BNC connectors.

Manuals and other useful information

[Easy SWR Indicator Assembly Manual (5/27/2017)]

Ordering Information

To order this kit, use the buttons below. (you do not have to have a PayPal account to pay for items using a credit card)

Payments are Fast and Secure with PAYPAL

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Easy SWR Indicator: $15.00	Add
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Pacific Antenna Return Policy

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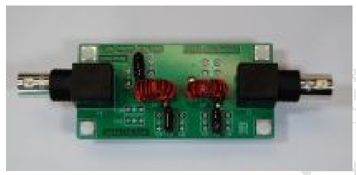
Easy Receiver

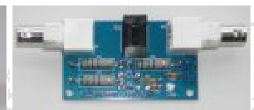

Easy Transmitter


Easy Audio Bandpass Filter


Easy TR Switch


Easy Field Strength Indicator


Easy Low Pass Filter


Easy SWR Indicator

Easy Receiver

Features

- Easy to build and use.
- No toroids to wind and only one adjustment to set the receive frequency.
- Assembles in 1-2 hours.
- Covers approximately 75kHz of the 40M band.
- Direct conversion design with a bandpass filter, NE602 mixer and LM386 audio amplifier.
- Mates with our Easy Transmitter and Easy Audio Filter to make a QRP station.

Manuals and other useful information

Easy Receiver for 40 Meters ver (5/27/2017)

Ordering Information

To order this kit, use the buttons below. (you do not have to have a PayPal account to pay for items using a credit card)

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Easy Receiver Kit: $25.00

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Easy Transmitter

Features

- VXO tuning range of approximately 1KHz on 40M
- Choice of 7.030 or 7.040 crystal
- Powered from 9-15V
- Output of approximately 2 W Designed for use with our Easy RX and Easy Bandpass Filter Kits
- Fun kit to build for anyone wanting a basic transmitter kit
- No toroids or coils to wind
- Can be built in 1-2 hours or less
- A great kit for new builders and club or group builds

Manuals and other useful information

Easy Transmitter for 40 Meters ver (11/08/2017)

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for your support!

Easy Transmitter Kit 40M (7.030 Crystal): $25.00 Add

Easy Receiver/Transmitter Combo Kit 40M (7.030 Crystal): $45.00 Add

Easy Receiver/Transmitter Combo Kit 40M (7.040 Crystal): $45.00 Add

Easy Transmitter Kit 40M (7.040 Crystal): $25.00 Add

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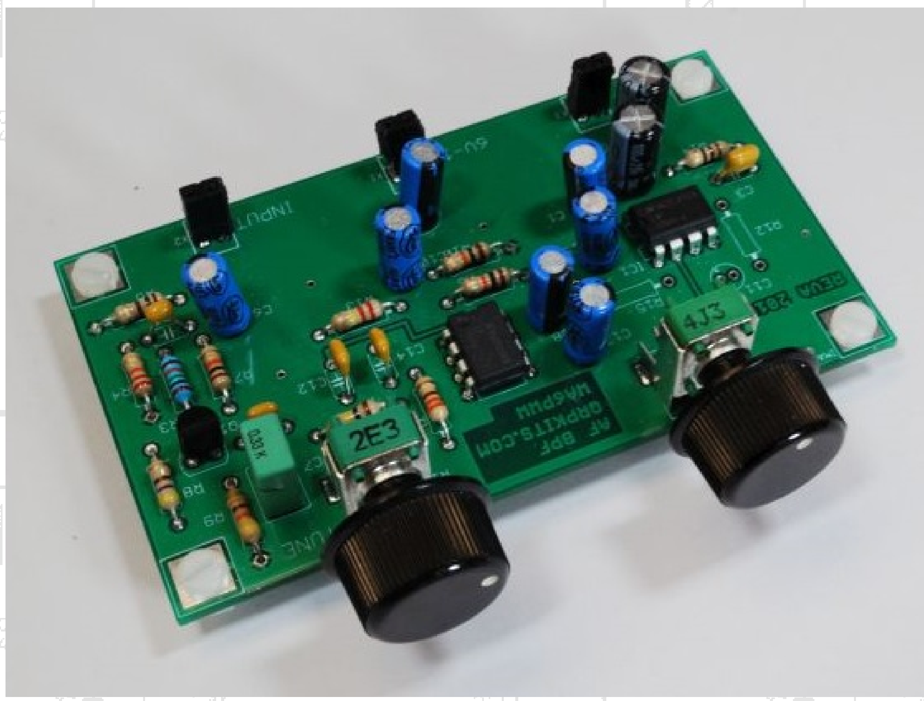
Easy Audio Bandpass Filter



Features

- A basic audio filter kit with preamp, op-amp filter and LM386 audio amp to drive headphones or speaker
- Has a peak in response that is tunable from approximately 300Hz to 2Khz
- Tuning and volume pots for adjustment
- Build in 1-2 hours or less
- Designed for use with our Easy RX kits or other radios to add audio filtering

Manuals and other useful information

Easy Audio Bandpass Filter ver 4 (5/27/2017)

Ordering Information

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Easy Bandpass Filter Kit: $25.00 Add

View your shopping cart: Check Out

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Easy TR Switch

Features

- A simple switch to provide transmit receive switching
- Has two separate switched sets of contacts
- RF sensing built in and activates with as little as 100mW of RF
- Can be hard keyed by grounding pins on control header
- Handles 150W of RF over 160-6M

Manuals and other useful information

Easy TR Switch Ver 3 (12/12/2017) UPDATED

Easy TR Switch Ver 2 (05/23/2017)

Ordering Information

To order this kit, use the buttons below. (you do not have to have a PayPal account to pay for items using a credit card)

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Easy TR Switch Kit: $20.00

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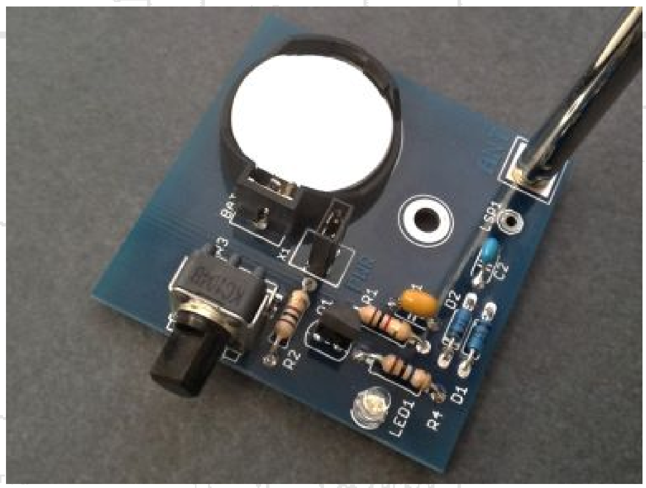
Easy Field Strength Indicator



Features

- Provides a visual monitor of RF fields through the brightness of an LED
- Responds to fields from approximately 1MHz to a few hundred MHz
- Circuit board is 1.75x1.75 inches
- Uses a high brightness LED to indicate field intensity
- Powered by a 2032 coin cell battery or external 3-9V power source
- Can be built into a housing or used stand alone

Manuals and other useful information

[Easy Field Strength Indicator Manual (12/14/2017] UPDATED

Ordering Information

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Easy Field Strength Indicator: $15.00	Add
Optional whip antenna: $2.50	Add
View your shopping cart:	Check Out

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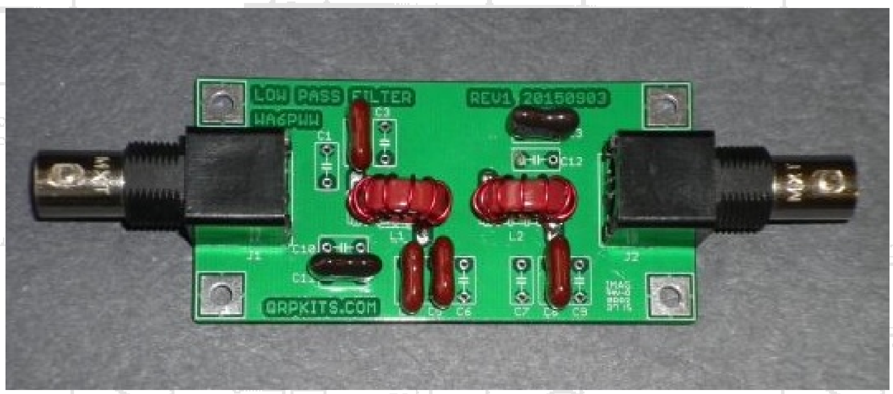
Easy Low Pass Filter



Features

Many basic transmitter and/or transceiver designs have minimal filtering on their output and frequently have significant harmonic content in their signals.

Our Easy Low Pass Filter kit from Pacific Antenna is 5 pole LC filter designed to reduce harmonics and spurious signals.

When properly configured, our low pass filter is capable of significantly reducing harmonics with minimal effect on the desired signal.

Ideal for reducing band to band interference for field day and contest stations.

This is a relatively simple kit to build and is ideal for beginners.

Specifications

- Versions available for 80, 40, 30 and 20 Meter bands
- Power handling up to 100W under matched conditions
- Reduction of harmonics by more than 50dB
- Constructed on a 1.75x 3.5 inch printed circuit board
- Designed to be placed inline between a transmitter and antenna
- Includes board mounted BNC connectors and all necessary parts

Manuals and other useful information

[Easy Low Pass Filter Assembly Manual (05/27/2017)]

Ordering Information

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Easy Lowpass Filter 20m: $15.00 Add

Easy Lowpass Filter 30m: $15.00 Add

Easy Lowpass Filter 40m: $15.00 Add

Easy Lowpass Filter 80m: $18.00 Add

View your shopping cart: Check Out

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Easy SWR Indicator

Features

- Designed for power levels of 0.2 to 5 Watts
- Provides protection for transmitter by limiting reflected power during tuneup
- Indicates match to antenna by dimming of LED
- Constructed on a 1.5x 2.5 inch printed circuit board
- Includes board mounted BNC connectors.

Manuals and other useful information

[Easy SWR Indicator Assembly Manual (5/27/2017)](#)

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Easy SWR Indicator: $15.00 Add

View your shopping cart: Check Out

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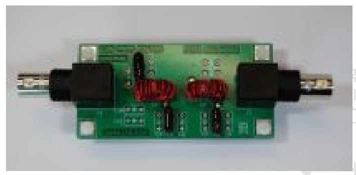
Easy Receiver

Easy Transmitter

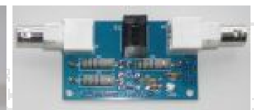
Easy Audio Bandpass Filter

Easy TR Switch

Easy Field Strength Indicator



Easy Low Pass Filter



Easy SWR Indicator

Easy Receiver

Features

- Easy to build and use.
- No toroids to wind and only one adjustment to set the receive frequency.
- Assembles in 1-2 hours.
- Covers approximately 75kHz of the 40M band.
- Direct conversion design with a bandpass filter, NE602 mixer and LM386 audio amplifier.
- Mates with our Easy Transmitter and Easy Audio Filter to make a QRP station.

Manuals and other useful information

Easy Receiver for 40 Meters ver (5/27/2017)

Ordering Information

To order this kit, use the buttons below. (you do not have to have a PayPal account to pay for items using a credit card)

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Easy Receiver Kit: $25.00

View your shopping cart:

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Easy Transmitter

Features

- VXO tuning range of approximately 1KHz on 40M
- Choice of 7.030 or 7.040 crystal
- Powered from 9-15V
- Output of approximately 2 W Designed for use with our Easy RX and Easy Bandpass Filter Kits
- Fun kit to build for anyone wanting a basic transmitter kit
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Manuals and other useful information

Easy Transmitter for 40 Meters ver (11/08/2017)

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for your support!

Easy Transmitter Kit 40M (7.030 Crystal): $25.00 Add

Easy Receiver/Transmitter Combo Kit 40M (7.030 Crystal): $45.00 Add

Easy Receiver/Transmitter Combo Kit 40M (7.040 Crystal): $45.00 Add

Easy Transmitter Kit 40M (7.040 Crystal): $25.00 Add

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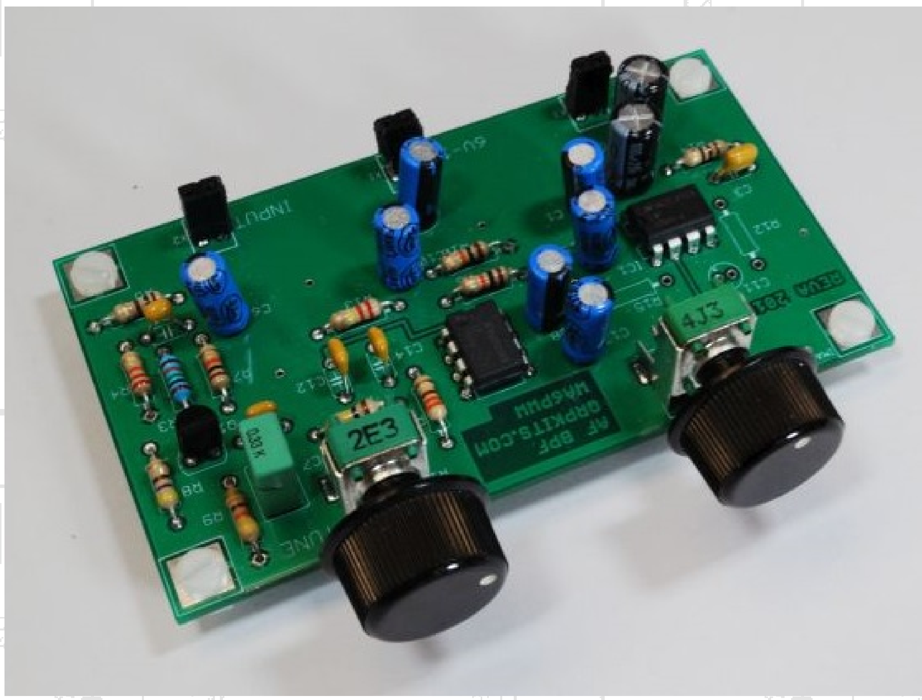
Easy Audio Bandpass Filter



Features

- A basic audio filter kit with preamp, op-amp filter and LM386 audio amp to drive headphones or speaker
- Has a peak in response that is tunable from approximately 300Hz to 2Khz
- Tuning and volume pots for adjustment
- Build in 1-2 hours or less
- Designed for use with our Easy RX kits or other radios to add audio filtering

Manuals and other useful information

Easy Audio Bandpass Filter ver 4 (5/27/2017)

Ordering Information

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Easy Bandpass Filter Kit: $25.00 Add

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Easy TR Switch

Features

- A simple switch to provide transmit receive switching
- Has two separate switched sets of contacts
- RF sensing built in and activates with as little as 100mW of RF
- Can be hard keyed by grounding pins on control header
- Handles 150W of RF over 160-6M

Manuals and other useful information

[Easy TR Switch Ver 3 (12/12/2017)](#) UPDATED

[Easy TR Switch Ver 2 (05/23/2017)](#)

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Easy TR Switch Kit: $20.00 Add

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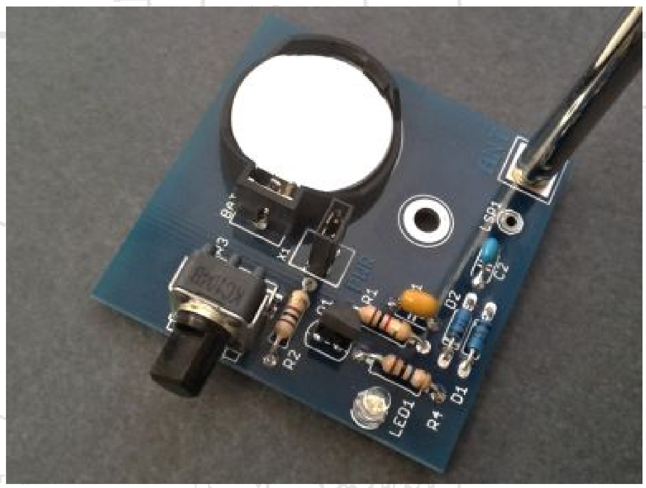
Easy Field Strength Indicator



Features

- Provides a visual monitor of RF fields through the brightness of an LED
- Responds to fields from approximately 1MHz to a few hundred MHz
- Circuit board is 1.75x1.75 inches
- Uses a high brightness LED to indicate field intensity
- Powered by a 2032 coin cell battery or external 3-9V power source
- Can be built into a housing or used stand alone

Manuals and other useful information

[Easy Field Strength Indicator Manual (12/14/2017](#) UPDATED

Ordering Information

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Easy Field Strength Indicator: $15.00 Add

Optional whip antenna: $2.50 Add

View your shopping cart: Check Out

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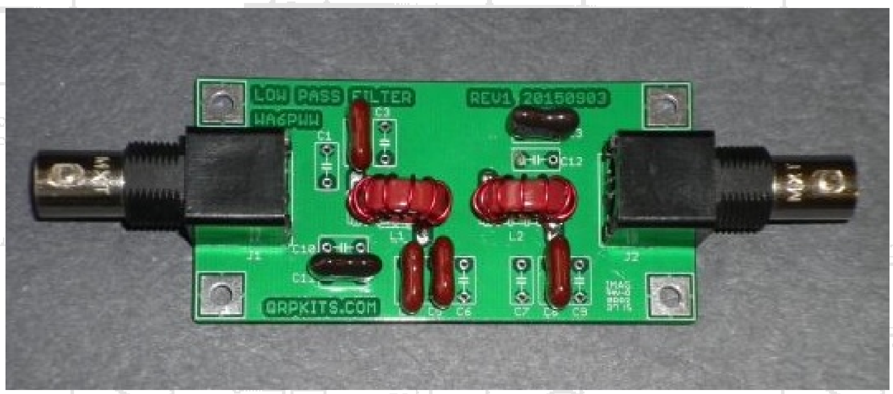
Easy Low Pass Filter



Features

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Manuals and other useful information

[Easy Low Pass Filter Assembly Manual (05/27/2017)]

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Easy Lowpass Filter 20m: $15.00 Add

Easy Lowpass Filter 30m: $15.00 Add

Easy Lowpass Filter 40m: $15.00 Add

Easy Lowpass Filter 80m: $18.00 Add

View your shopping cart: Check Out

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Easy SWR Indicator

Features

- Designed for power levels of 0.2 to 5 Watts
- Provides protection for transmitter by limiting reflected power during tuneup
- Indicates match to antenna by dimming of LED
- Constructed on a 1.5x 2.5 inch printed circuit board
- Includes board mounted BNC connectors.

Manuals and other useful information

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Easy SWR Indicator: $15.00 Add

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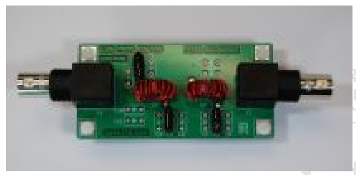
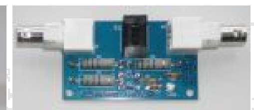

Easy Low Pass Filter


Easy SWR Indicator

Easy Receiver

Features

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- No toroids to wind and only one adjustment to set the receive frequency.
- Assembles in 1-2 hours.
- Covers approximately 75kHz of the 40M band.
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Manuals and other useful information

Easy Receiver for 40 Meters ver (5/27/2017)

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View your shopping cart: Check Out

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Easy Transmitter

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- Choice of 7.030 or 7.040 crystal
- Powered from 9-15V
- Output of approximately 2 W Designed for use with our Easy RX and Easy Bandpass Filter Kits
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- A great kit for new builders and club or group builds

Manuals and other useful information

Easy Transmitter for 40 Meters ver (11/08/2017)

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Easy Receiver/Transmitter Combo Kit 40M (7.040 Crystal): $45.00	Add
Easy Transmitter Kit 40M (7.040 Crystal): $25.00	Add
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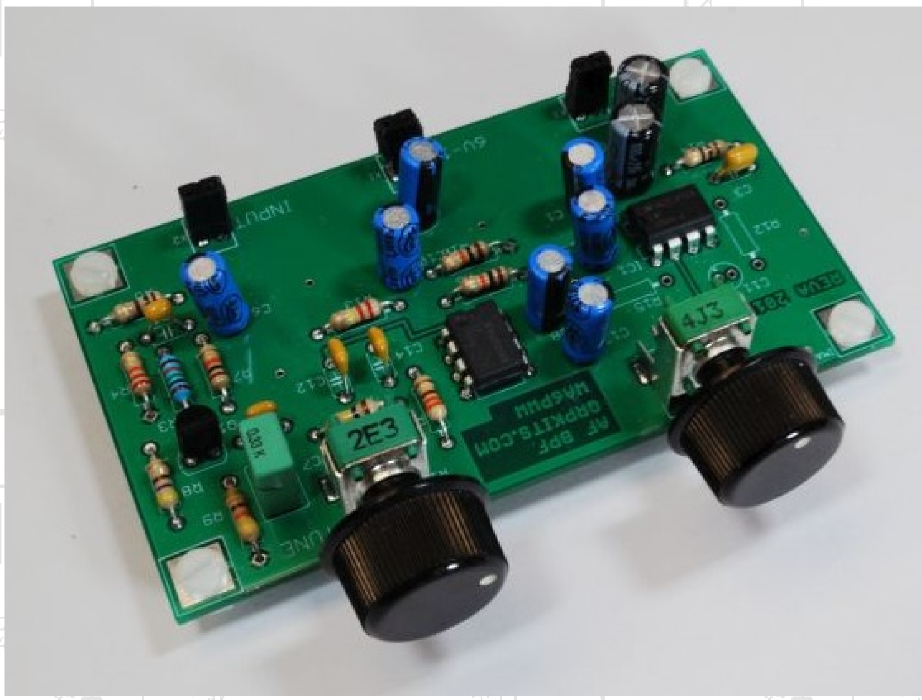
Easy Audio Bandpass Filter



Features

- A basic audio filter kit with preamp, op-amp filter and LM386 audio amp to drive headphones or speaker
- Has a peak in response that is tunable from approximately 300Hz to 2Khz
- Tuning and volume pots for adjustment
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- Designed for use with our Easy RX kits or other radios to add audio filtering

Manuals and other useful information

Easy Audio Bandpass Filter ver 4 (5/27/2017)

Ordering Information

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Easy Bandpass Filter Kit: $25.00 Add

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Easy TR Switch

Features

- A simple switch to provide transmit receive switching
- Has two separate switched sets of contacts
- RF sensing built in and activates with as little as 100mW of RF
- Can be hard keyed by grounding pins on control header
- Handles 150W of RF over 160-6M

Manuals and other useful information

Easy TR Switch Ver 3 (12/12/2017) UPDATED

Easy TR Switch Ver 2 (05/23/2017)

Ordering Information

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Easy TR Switch Kit: $20.00 — Add

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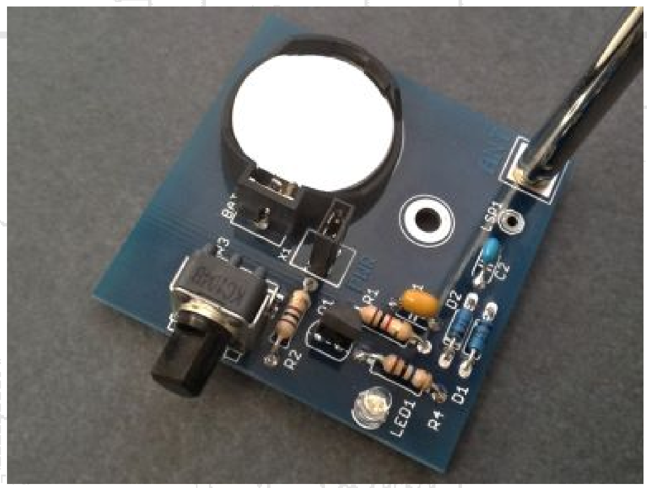
Easy Field Strength Indicator



Features

- Provides a visual monitor of RF fields through the brightness of an LED
- Responds to fields from approximately 1MHz to a few hundred MHz
- Circuit board is 1.75x1.75 inches
- Uses a high brightness LED to indicate field intensity
- Powered by a 2032 coin cell battery or external 3-9V power source
- Can be built into a housing or used stand alone

Manuals and other useful information

[Easy Field Strength Indicator Manual (12/14/2017](#) UPDATED

Ordering Information

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Easy Field Strength Indicator: $15.00 Add

Optional whip antenna: $2.50 Add

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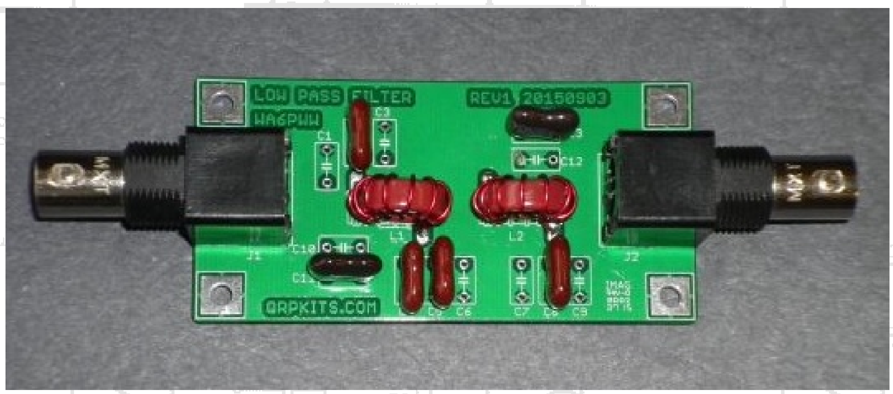
Easy Low Pass Filter



Features

Many basic transmitter and/or transceiver designs have minimal filtering on their output and frequently have significant harmonic content in their signals.

Our Easy Low Pass Filter kit from Pacific Antenna is 5 pole LC filter designed to reduce harmonics and spurious signals.

When properly configured, our low pass filter is capable of significantly reducing harmonics with minimal effect on the desired signal.

Ideal for reducing band to band interference for field day and contest stations.

This is a relatively simple kit to build and is ideal for beginners.

Specifications

- Versions available for 80, 40, 30 and 20 Meter bands
- Power handling up to 100W under matched conditions
- Reduction of harmonics by more than 50dB
- Constructed on a 1.75x 3.5 inch printed circuit board
- Designed to be placed inline between a transmitter and antenna
- Includes board mounted BNC connectors and all necessary parts

Manuals and other useful information

[Easy Low Pass Filter Assembly Manual (05/27/2017)]

Ordering Information

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Payments are Fast and Secure with PAYPAL

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Easy Lowpass Filter 30m: $15.00	Add
Easy Lowpass Filter 40m: $15.00	Add
Easy Lowpass Filter 80m: $18.00	Add
View your shopping cart:	Check Out

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Easy SWR Indicator

Features

- Designed for power levels of 0.2 to 5 Watts
- Provides protection for transmitter by limiting reflected power during tuneup
- Indicates match to antenna by dimming of LED
- Constructed on a 1.5x 2.5 inch printed circuit board
- Includes board mounted BNC connectors.

Manuals and other useful information

Easy SWR Indicator Assembly Manual (5/27/2017)

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Easy SWR Indicator: $15.00 Add

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Pacific Antenna

Affordable QRP Antennas and Kits at exceptional value

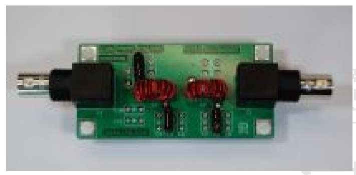

Easy Receiver

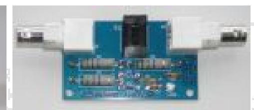

Easy Transmitter


Easy Audio Bandpass Filter


Easy TR Switch


Easy Field Strength Indicator


Easy Low Pass Filter


Easy SWR Indicator

Easy Receiver

Features

- Easy to build and use.
- No toroids to wind and only one adjustment to set the receive frequency.
- Assembles in 1-2 hours.
- Covers approximately 75kHz of the 40M band.
- Direct conversion design with a bandpass filter, NE602 mixer and LM386 audio amplifier.
- Mates with our Easy Transmitter and Easy Audio Filter to make a QRP station.

Manuals and other useful information

Easy Receiver for 40 Meters ver (5/27/2017)

Ordering Information

To order this kit, use the buttons below. (you do not have to have a PayPal account to pay for items using a credit card)

Payments are Fast and Secure with PAYPAL

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Easy Receiver Kit: $25.00 Add

View your shopping cart: Check Out

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Easy Transmitter

Features

- VXO tuning range of approximately 1KHz on 40M
- Choice of 7.030 or 7.040 crystal
- Powered from 9-15V
- Output of approximately 2 W Designed for use with our Easy RX and Easy Bandpass Filter Kits
- Fun kit to build for anyone wanting a basic transmitter kit
- No toroids or coils to wind
- Can be built in 1-2 hours or less
- A great kit for new builders and club or group builds

Manuals and other useful information

[Easy Transmitter for 40 Meters ver (11/08/2017)](#)

Ordering Information

To order this kit, use the buttons below. (you do not have to have a PayPal account to pay for items using a credit card)

Payments are Fast and Secure with PAYPAL

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for your support!

Easy Transmitter Kit 40M (7.030 Crystal): $25.00

Easy Receiver/Transmitter Combo Kit 40M (7.030 Crystal): $45.00

Easy Receiver/Transmitter Combo Kit 40M (7.040 Crystal): $45.00

Easy Transmitter Kit 40M (7.040 Crystal): $25.00

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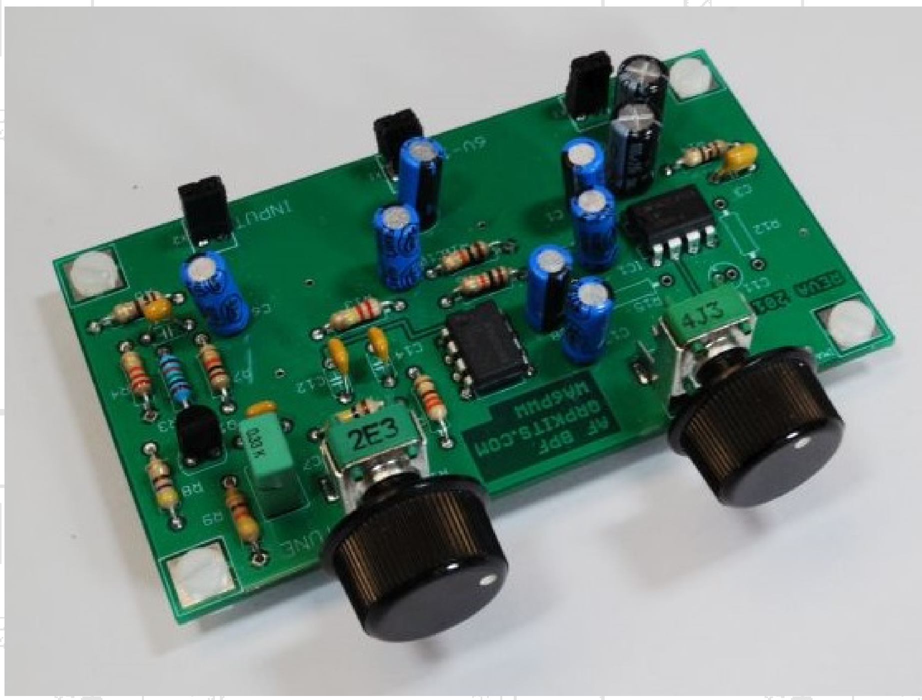
Easy Audio Bandpass Filter



Features

- A basic audio filter kit with preamp, op-amp filter and LM386 audio amp to drive headphones or speaker
- Has a peak in response that is tunable from approximately 300Hz to 2Khz
- Tuning and volume pots for adjustment
- Build in 1-2 hours or less
- Designed for use with our Easy RX kits or other radios to add audio filtering

Manuals and other useful information

Easy Audio Bandpass Filter ver 4 (5/27/2017)

Ordering Information

To order this kit, use the buttons below. (you do not have to have a PayPal account to pay for items using a credit card)

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Easy Bandpass Filter Kit: $25.00 Add

View your shopping cart: Check Out

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Manuals and other useful information

Easy TR Switch Ver 3 (12/12/2017) UPDATED

Easy TR Switch Ver 2 (05/23/2017)

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Easy TR Switch Kit: $20.00	Add
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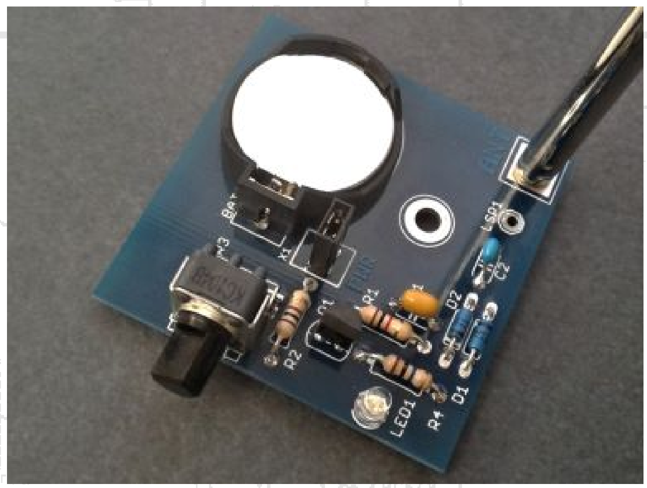
Easy Field Strength Indicator



Features

- Provides a visual monitor of RF fields through the brightness of an LED
- Responds to fields from approximately 1MHz to a few hundred MHz
- Circuit board is 1.75x1.75 inches
- Uses a high brightness LED to indicate field intensity
- Powered by a 2032 coin cell battery or external 3-9V power source
- Can be built into a housing or used stand alone

Manuals and other useful information

[Easy Field Strength Indicator Manual (12/14/2017](#) UPDATED

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Easy Field Strength Indicator: $15.00 Add

Optional whip antenna: $2.50 Add

View your shopping cart: Check Out

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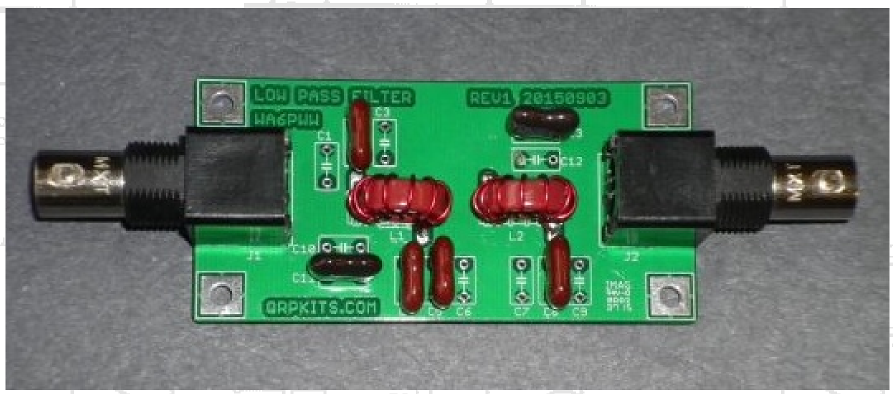
Easy Low Pass Filter



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Manuals and other useful information

[Easy Low Pass Filter Assembly Manual (05/27/2017)](#)

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Easy Lowpass Filter 20m: $15.00 — Add

Easy Lowpass Filter 30m: $15.00 — Add

Easy Lowpass Filter 40m: $15.00 — Add

Easy Lowpass Filter 80m: $18.00 — Add

View your shopping cart: Check Out

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Easy SWR Indicator

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Manuals and other useful information

Easy SWR Indicator Assembly Manual (5/27/2017)

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Pacific Antenna Return Policy

A very selective and high performance crystal radio
My Heathkit model CR-1

A comprehensive story containing historical, educational, technical and biographical elements & opinions
by
John Fuhring

If you found this page while looking for a simple, but great performing little radio that you can build yourself, you might be more interested in reading about

An Armstrong "Crystal" Radio

Rebuilding my Heathkit CR1 and getting it to work

I can not really remember when or how I came by this little radio, but it was many years ago. I seem to recall that I picked it up cheap at a thrift store as a non-functional item that had been poorly or incompletely put together. I remember that some of the screws and a connection post was missing and the parts weren't soldered in properly or correctly. To tell the truth, I didn't know how the radio was supposed to be wired and I must not have been very interested in getting it working, so it sat in a cabinet for several years until a year or so ago.

My CR-1 crystal radio modified for two earphone jacks.

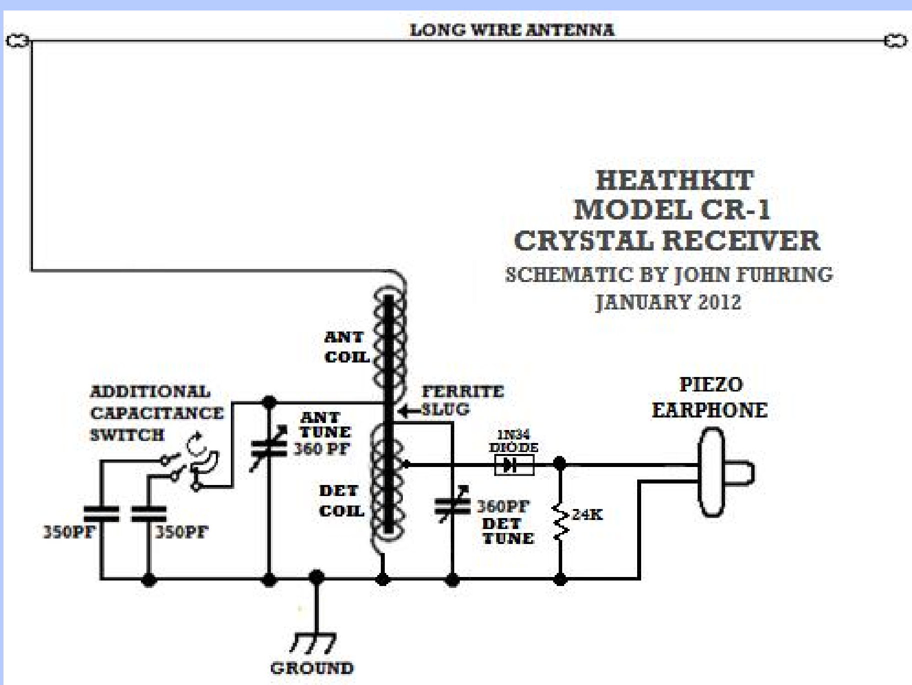
About a year ago I came across the little radio and decided that I would figure out how it was supposed to work and then I'd put it together correctly. The first thing I did was put a sub-miniature phone jack in place of the missing binder post since my piezo earphone has a sub-miniature plug on it and besides, I didn't have a matching binding post to replace the missing one. I took off the grounded binding post and put a screw to cover the hole. Next I soldered the antenna tuner coil to its variable capacitor and wired the two fixed capacitors to the selector switch. I then soldered the station tuning coil side to its variable capacitor and from the tap on the station tuner coil, I soldered a 1N34 germanium detector diode to the phone jack. By the way, Heathkit called the tuning capacitor connected to the station tuning coil the "detector tuner" and on the panel it is labeled as "DET"

for detector.

Back side showing the radio's components.
The antenna and the station tuning coils are wound on the phenolic tube. The antenna coil is to the left of center. A powdered iron (ferrite) slug is inside the tube between the two coils.

When I finished soldering everything in correctly, I connected the little set to my antenna & ground and soon I could clearly hear my local AM stations, but I noticed that the tuning dial seemed to be way off. At the very top of the AM dial (around 1600) I know there is a very strong Mexican station, but I couldn't go high enough to tune it in. To match the dial with the AM band, I took a thin wooden stick and gently pushed on the ferrite slug in the coil form until it was nearly centered between the two sets of coils. By moving the slug, I was able to match the dial to about where I knew my local stations were and was able to hear the Mexican station near the top of the dial. The slug is held inside the tube by wax and if you are careful and apply slow, even pressure, the slug will move to where you want it.

I now had a crystal radio put together as it should be and it worked -- sort of. Below is the schematic diagram I developed for the little radio. I'm kind of big on schematic diagrams, but I wasn't always so.



My schematic diagram of the Heathkit model CR-1 crystal radio.

In many respects, this design operates on similar principles to the "Trench Radios" of WW 1. Military radios of that day, such as the US

Army's BC-14/SCR-54, also used antenna tuning, light coupling between stages, a tuned diode section and they operated on the same range of frequencies, 550-1600 KHz.

I understand that these kits were very popular with Boy Scouts and were marketed as a kind of a "Survivor's Radio" during the worst parts of the "Cold War" when my government's Civil Defense planners expected an Atomic War with the USSR to break out at any time. With only a few CONELRAD stations on the air and with us few survivors trapped in "bomb shelters" for months and years, with our entire civilization and economy wrecked, still, news and information would be available to any doomed citizen having one of these radios, even though there was no electricity and the battery operated radios had all gone dead. Doesn't that sound cozy? Doesn't that sound like fun? Well, at least we would be "better off dead than red" and, being dead, we'd not have to "live under godless communism."

Oh, weren't the "Good Old Days" just wonderful?!?

At the time I first got this little radio working, all I had was a short outside antenna that I used with my one-tube regenerative radio and my EC-1 shortwave radios. To tell the truth, when I connected the Heathkit crystal radio up to my rather poor antenna, I was very much UN-impressed with this radio. Compared to my Armstrong regenerative radio (written about elsewhere on this website), it performed very poorly and all I could receive was my four really strong local AM stations. You know, there is nothing on my local AM radio except all this mean, downright goofy, unpatriotic right-wing hate talk or the even more disgusting and ignorant Fundamentalist preaching, none of which I can stand to listen to, but there is a Mexican music and local talk station that wouldn't be bad if I understood a word of Spanish. With nothing to listen to, I lost interest and did nothing more with the radio.

Surprising performance from this kind of radio

A few weeks ago I vastly improved my outside antenna and had some fun using it to do some AM DX listening with my 1958 Armstrong one tube regenerative radio. One evening, a few days ago, the AM signals were coming in from San Francisco, Los Angeles and Reno very strongly and so I started wondering if the crystal radio could pick them up too. I was very skeptical because the crystal radio had never performed all that well, but now I had a better antenna and maybe things would be different.

When I connected the crystal radio to my long wire antenna, I was pleased to discover that both the station tuning AND the antenna tuning sections now worked together to make the tuning very sharp. Before, with the short antenna, the antenna tuning section didn't seem to do anything and I was wondering what it was put in there for, but now it worked and I was extremely impressed with how selective the radio could be for a crystal set. Strong stations that had once blended together now could be separated and the strong stations didn't bleed on to the weaker stations. So, with the radio working better than at any time since I rebuilt it, I tuned to about where KGO up in San Francisco should be (middle of the dial at 810 KHz). Wow! by carefully adjusting both tuners, I could hear KGO loud and clear and without other stations overlapping. By the way, KGO is about the last station on AM that hasn't been taken over by the right-wing propagandists or America's own brand of the Talaban and they feature real people talking about real things that matter to people and not the steady diet of political and religious garbage that dominates nearly all of AM these days. Sadly, when KGO goes silent, I'm sure someday it will, AM radio will be well and truly dead.

Listening to this simple little radio pull in distant stations like that was a kind of "radio communications epiphany" for me. I always wondered how ships like the Titanic could communicate with other ships and to shore stations with nothing more than Fleming Valve or crystal radio receivers. My experience with this little radio has shown me how, with a good antenna and good sharp tuning circuits, individual radio signals can be picked out from a mass of signals out there and can be heard from a long way off. For me, this is a very wonderful thing, especially when I consider that these radios do not amplify their signals, but use the tiny electrical energy that is picked up by the antenna to make sound. Such is the extreme sensitivity of human hearing and the amazing efficiency of the circuits, detector crystal and earphones that microwatts of power, originally coming from a station hundreds of miles away and landing on my antenna wire, can be heard clearly.

The way this radio works is as basic as it is possible to get
and here's how it all works:

Imagine that there is a radio station 10 miles away and that it that is broadcasting radio waves at 1,400 KHz. Imagine that our radio station is broadcasting hundreds of watts of energy into space and that if we could capture just a tiny amount of this energy, we would be able to hear what was being broadcasted. Imagine that we have a crystal radio like the one above connected to a long wire antenna.

(1) The passing radio wave from our station induces a tiny high frequency voltage on our antenna wire. The antenna is connected to the antenna coil (coil on the top of the diagram) with its antenna tuning capacitor to the left and below it.

(2) When the antenna capacitor is tuned just right so that the inductance of the coil is matched by the capacitance of the tuning capacitor, a tiny current from the antenna flows in the antenna coil to produce an oscillating (or varying) magnetic field inside the antenna coil. By carefully adjusting the antenna tuning capacitor, this oscillating magnetic field will be right in tune with 1,400 KHz and 1,400 KHz only. This is important because it helps seperate our 1,400 KHz signal from all the others on the AM band.

(3) The oscillating magnetic field inside the antenna coil is coupled over to the other coil (the station tuning coil) through the well known principle of "Mutual Inductance" discovered by Michael Faraday in the 1830s.

(4) The 1,400 KHz signal that has been coupled to the station tuning coil is contained in a "tank circuit" that is made up of the station tuning coil and the station tuning capacitor (shown to the coil's right).

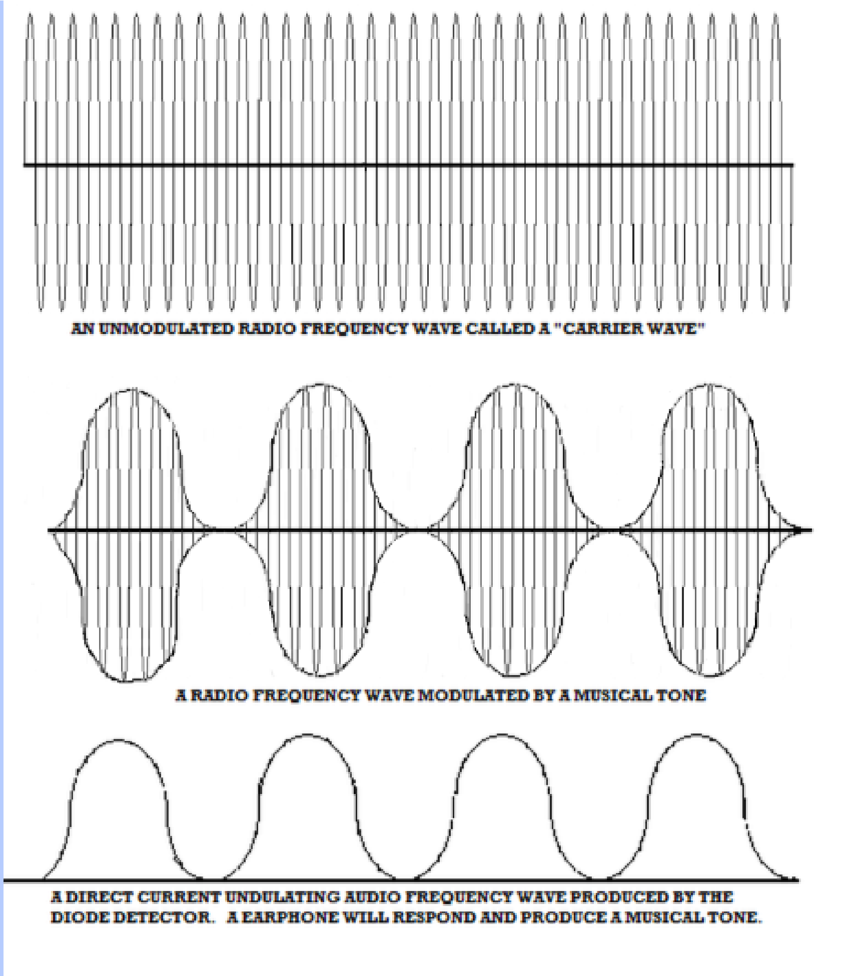
(5) By carfully adjusting the station tuning capacitor so that its capacitance exactly matches the coil's inductance, a so-called tank circuit is formed. This tank circuit "resonates" or "tunes in" the 1,400 KHz signal and that means that it further seperates our 1,400 KHz signal from all the other nearby signals. We now have just the radio signal we want, but we need to do more because it is impossible for our ears to hear radio frequency signals.

(6)
To "detect" the presence of the radio frequency signal that is resonating in the tank circuit, some of the tank's energy is tapped off near the bottom of the station tuning coil and it is wired to one side of the 1N34 detector diode.

(7)
The 1N34 diode chops off the negative part of the radio frequency wave. The detector needs to do that or the negative part of the wave would cancel out the positive part of the wave and nothing would be heard.

(8)
When the diode detector chops off part of the radio frequency signal, direct current audio frequency undulations are all that are left over from the original radio wave. These direct current audio frequency undulations correspond to the sound being transmitted by the station and when the wires of a very sensitive earphone are connected to the detector, these undulations of direct current cause the mechanism inside the earphone to vibrate in step with the undulations and it is those vibrations that we hear as sound.

Here is a graphical representation of what's going on when a radio frequency signal is detected (turned into sound):



Graphs of the various waveforms seen at the tuner stage (top two) and at the detector stage. Unmodulated carrier waves are also called "continuous waves" and can't be heard by a crystal detector except as a kind of a very faint hissing noise. AM radio stations try to avoid sending out unmodulated carrier waves (called "dead air") and so this waveform is rarely seen. More common is the waveform showing lower frequency sound waves superimposed on the carrier wave.

The dark black line is where the voltage is zero as a carrier wave crosses from positive to negative. As shown here, the negative going parts of the wave are stopped by the detector diode so that positive to zero to positive undulations remain. If you reverse the diode, the direct current undulations will be negative to zero to negative, but the same musical tone will be heard in the earphone.

Most crystal radios use only one half of a radio frequency's wave.

The importance of a good antenna and ground system

These radios are not connected to your house's AC power and they use no batteries. A crystal radio has no amplifying circuits and yet they output sound and sound is energy. Where do they get the energy to make sound? Do they somehow use mysterious and occult "free energy from space" or something goofy like that? The energy needed to run these radios doesn't cost you anything directly, but it isn't free or mysterious. The energy is from a tiny fraction left over from the hundreds of watts of radio frequency energy a station broadcasts out to space. The vast, vast majority of the energy a broadcast station radiates out of its antenna system is lost, but a tiny fraction of it may be picked up by an antenna at somebody's house.

Antennas for listening to AM stations can range from tiny "loop" antennas that are extremely inefficient, but good enough for amplified radios, all the way to elaborate "long wire" systems dozens and dozens of feet long and high up in the air. The general rule was discovered by Marconi over a hundred years ago that the longer and higher the antenna, the better it is at capturing some of that energy that is passing by. To produce enough energy so that it can be processed inside the crystal radio circuits and then come out as sound energy strong enough to vibrate the mechanism inside the earphone, the antenna needs to be as long and as high as is practical. Practical is what you have room for and how high you can safely go. Practical antennas can be strung between poles located at the ends of a roof or from the house out to a distant tree or pole. It is true that antennas longer than 60-100 feet and higher than 25 feet do capture more energy, but things soon get very difficult and for very little extra gain at distances and heights beyond what is practical.

In addition to a really good long wire antenna (as long as is practical as mentioned), this radio must have a good ground. Right now, I am using my house's wiring as a ground and it seems to work well. Water pipes, when available to connect to, are supposed to work even better. When using house wiring, it would be a deadly mistake to connect to anything but the AC ground, so be careful.

Sensitive, high impedance headphones or earphones are a must

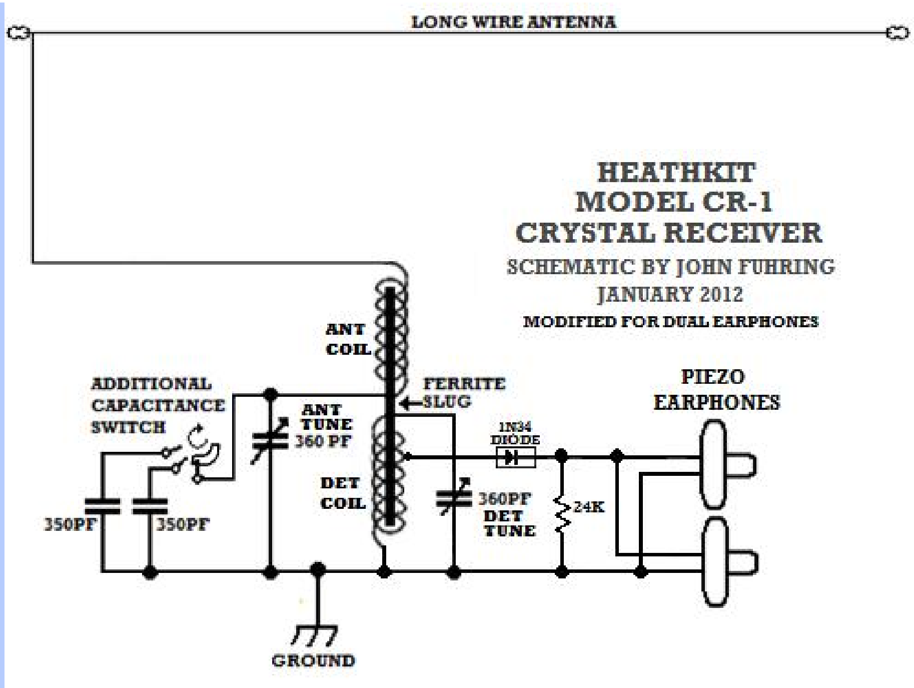
This radio works reasonably well with good quality high impedance headphones, but my very inexpensive piezoelectric earphone is noticeably louder on weak signals. The tapped tuning coil matches high impedance headphones, but for best selectivity (ability to separate close-by stations), the even higher impedance piezoelectric earphone works best.

A modification so I can use two earphones

After using this little radio set for several days, I had a "brilliant" idea. Since only one side of the radio frequency wave is being "detected" (or rectified) and being turned into undulating direct current waves, what about the other side of the radio frequency wave? Couldn't I detect it too, only in reverse and end up with two direct current waves of opposite polarity so that I could connect up separate earphones? Sure, why not, so that's exactly what I did. I installed a second phone jack and a second 1N34 diode only the new one is in reverse of the other. Then I did some testing and even more testing today. I hate to admit it, but the truth is, I can barely detect a any real difference between using a separate detector and just connecting the second earphone to the same diode. By the way, I noticed some "rattling" on the stronger signals while having two earphones connected, but when I put 24,000 ohm (1/4 watt) loads across the earphones, the tuning didn't seem to be effected, the sound quality improved and the "rattle" was gone.

When I first tried this dual diode system out, there seemed to be a real improvement over using two earphones off the same diode, especially on really weak signals, but on further testing, that difference appears to be minimal at best. At first I was surprised that I had never seen or heard of anybody doing this back in the early days of radio when family members would share a headphone, but now I'm not so sure this is a good idea after all. The theory looks good, but in practice, it's hardly worth doing.

Here's what the circuit now looks like with two earphones connected to the same diode:



The Heathkit CR-1 modified for two earphones.

Even though using an extra diode didn't really improve the operation of my crystal set as much I thought it would, I liked the idea of having an extra jack for another earphone so I installed it. I can now share my radio's output with somebody else in the bomb shelter in case Atomic War breaks out. Doesn't THAT sound like fun? Seriously, listening with both ears improves my listening experience -- now if there was just something worth listening to.

Tuning this radio for maximum sensitivity and selectivity

The trick to tuning this radio is to first locate a strong local station of known frequency and tune it in with both the antenna tuner and the station tuning controls. If the setting of the antenna tuning control doesn't seem to make much difference, try switching in extra capacitance, but if that doesn't help, consider stringing up a longer antenna. Both controls should be used to peak the signal for maximum loudness. Once you have an idea where on the dial your station is located, move both controls to about where you guess the weaker station you want to listen to might be. Once there, slowly and carefully adjust the station tuning until you hear something and then peak it up with the antenna tuning control. You may have to go back and forth a few times to get maximum volume with minimum interference from nearby and stronger stations. The radio has a switch to add additional capacitance if the variable capacitor isn't enough, but so far I haven't used an antenna that requires extra capacitance.

One of the shortcomings of this and most other crystal radios is that the tuning dial is not calibrated in frequency, but is simply numbered from 100 to 0. It is doubly difficult to try to set the tuning knob with this radio because the larger the number, the lower the frequency. For example, if the station you want to listen to is at 1600 KHz on the AM dial, the Heathkit must be tuned between 10 and 0, if the station is at 800 KHz, set the dial to 50. What is really ironic is that Heathkit put frequency markers on the station tuning control for the Civil Defense frequencies (640 KHz & 1440 KHz), but they left it up to you to guess where the other frequencies should be. Setting the antenna tuning is equally important and again the numbers are backward. For the highest frequencies, the setting is 0 and for the lowest frequencies, the setting is 100.

The best time of the day to have fun with these kinds of radios

During the daytime and during the summer months, about all that can be received with a little set like this, at least around here, is the trash in English that the local broadcasters pander to and a couple of Mexican language and music stations, but in the evening, electrified layers way up high in the outer fringes of the atmosphere allow radio waves to be bent back down to earth so that interesting stations worth listening to, but which are 200 to 300 (sometimes even more) miles away may be heard loudly and clearly. This long distance "refraction" or bending of the radio waves back to earth (a process called "skip") makes it possible to hear these distant stations, but it isn't like listening to the station next door. This "skipping" of radio waves off electrically charged layers in the upper atmosphere makes these signals subject to all kinds of things including interference from

even more distant stations, fading in and out, some strange sounding distortions and sometimes there is even an echo effect. These so-called "propagation effects" can be annoying, but if you just wait a few seconds or minute or so, the signal generally returns.

I think that listening for yourself, to hear what Nature is doing to these signals way up in the sky, is part of what makes listening to the Broadcast Band at night so interesting. There is a certain randomness to this skip that is explained to some degree by solar astronomy and physics. Scientists and engineers all over the world closely monitor our local star and measure it for electrical and magnetic activity. Reports and prediction tables are compiled by various scientific agencies and all this stuff is available on the Internet. When you can test these predictions for yourself by listening for "skip," you are participating in a scientific observation in your own little way.

Listening to far distant stations with a crystal radio like this one shows you how ships like the Titanic could communicate with other ships and to shore stations hundreds of miles away with nothing more than crystal radio receivers. Speaking of the Titanic, two thirds of all the people on her died, but without early radios, very much like this crystal set, everybody would have died. If you make one of these radios and actually put it to use, you will see how, with a good antenna and good sharp tuning circuits, individual radio signals can be picked out from the mass of signals out there and your station can be heard from a long way off under the right conditions. For me, this is a very wonderful thing, especially when I consider that these radios do not amplify their signals, but use the tiny amounts of electrical energy that is picked up by the antenna to make sound. Such is the extreme sensitivity of human hearing and the amazing efficiency of the circuits, the detector crystal and the earphone, that microwatts of power, originally coming from a station hundreds of miles away and landing on my antenna wire, can be heard clearly.

How far we have come

When you think about it, it seems that such basic radio technology represented by this little crystal radio is quite old, but in fact, the first Fleming Valve and crystal radios were invented just a little over 100 years ago. When my mother was a girl, people were building crystal sets so that they could listen to the wonderful new radio broadcasts from the big cities. In a relatively short span of time, the time since my grand parents were young in the 1890s to my parent's time, to this very moment, consider just how far we have come with radio, television, GPS, cell phones, satellite broadcasting, wireless Internet, interplanetary missions to space and so much allied technology.

The End

Having arrived this far, obviously you have a superior attention span and reading ability that far exceeds that of the majority of web users. I highly value the opinion of people such as yourself, so I ask you to <u>briefly</u> tell me:

Did you enjoy this article or were you disappointed?

Please visit my guest book and tell me before you leave my website.

If you have any detailed comments, questions, complaints or suggestions, I would be grateful if you would please **E-mail me directly**

If you are a science student or hobbyist, you might be interested in building a radio
that is as simple and cheap to build as a basic crystal radio, but hundreds of times better,
you might like this recommended article:.

An Armstrong "Crystal" Radio

from "The Old Geezer Electrician"

If you are looking to build something with the same great performance as the Armstrong "Crystal" Radio, but looks a whole lot nicer, I would like to suggest

The Geezerola Senior radio

I have also built a tiny crystal radio based on some of the good design features of the CR1.

My homemade high performance crystal radio.

Please note that this radio performs poorly compared to the Armstrong "Crystal" Radio.

If you are interested in simple vacuum tube regenerative radios, perhaps you would like to read the story of

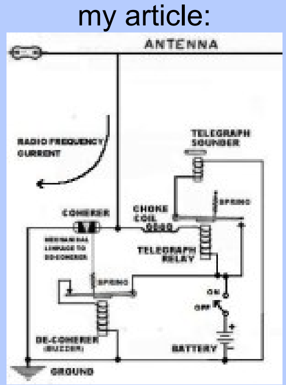
My Armstrong regenerative radio I built in 1958

This is the radio that launched my career in electronics and which the Armstrong "Crystal" Radio is based on.

Perhaps you would like the story of my Armstrong regenerative radio that tunes shortwave,

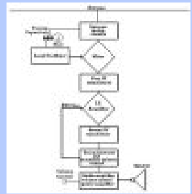
My Regenerative Shortwave Radio.

If you are curious how the first practical radios were designed and how they worked, you might be interested in my article:



The Coherer and other detectors used in early radio

For more on basic radio design, I have written a little essay you might like that explains some of the principles behind



How The Armstrong Superheterodyne Radio Works

or you can

Select some other really entertaining radio article

or, as a last resort, you can

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Alan's Lab

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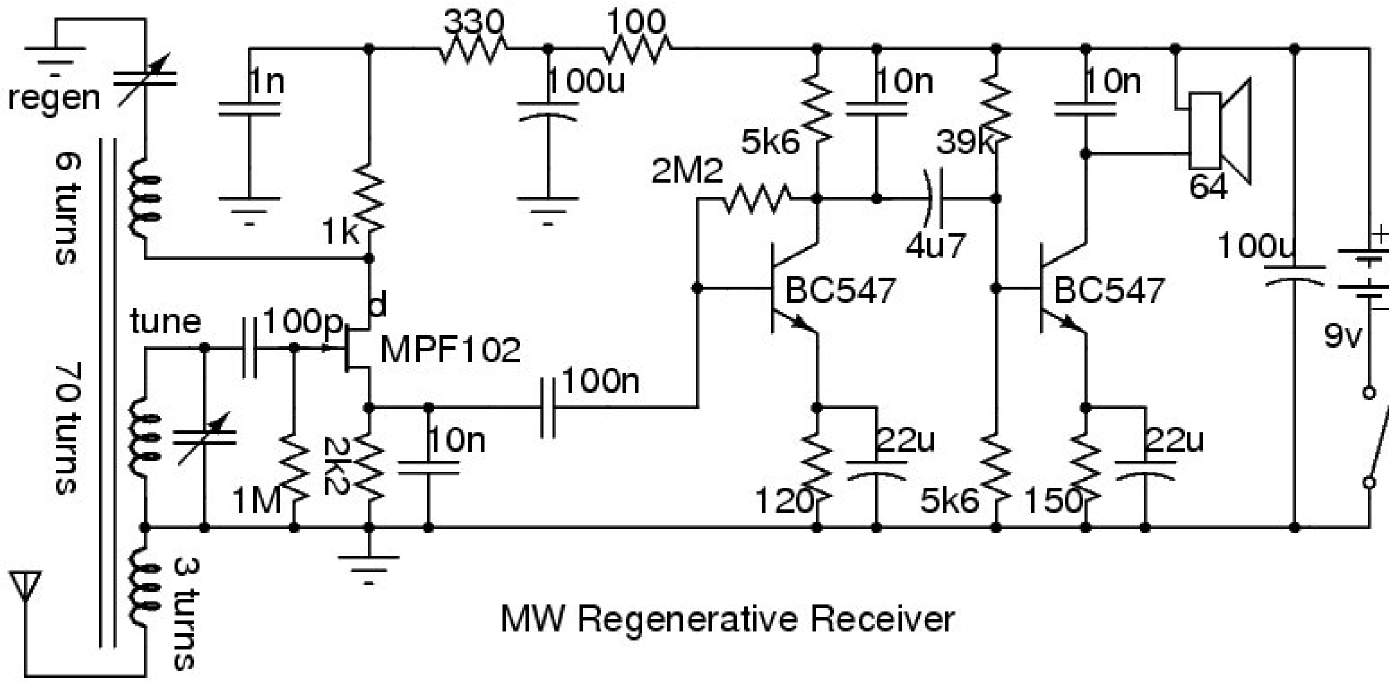
MW Regenerative Receiver

2006-08-06

This radio is based on the Moorabbin Receiver. The Regenerative detector is basically identical, however the audio stage in the original radio is dependant on a transformer that is now quite expensive in Australia. I also believe the gain of the original audio stage is insufficient for comfortable listening with weak signals.



MW Regenerative Receiver

The audio pre-amp stage is biased to 750 uA. It is somewhat noisy. Metal film resistors and a transistor with lower noise and better gain at a lower collector current would perform better. (Try a BC550 or BC549C.) However, it is simple and works quite well. You can increase the 10n capacitor in the collector to roll-off the HF response earlier if you find the audio a little tinny. (Doing so will also kill off much of the noise the stage produces.)

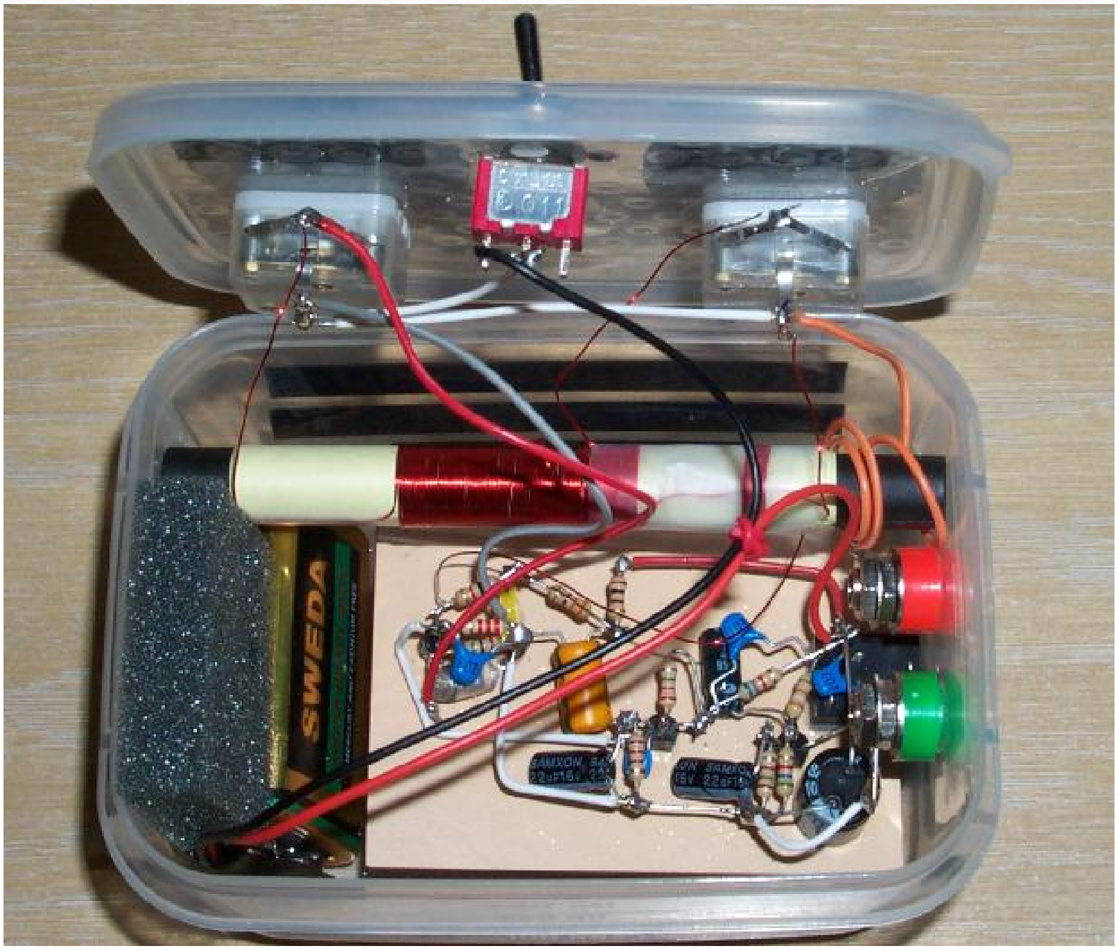
The audio "power-amp" is a simple class A affair, biased to 3.5 mA standing current. The DC passes through the speakers, this might be considered undesirable, but is safe at such a low level. Like all such primitive circuits it suffers from positive-going amplitude distortion as the beta of the device changes with its collector current. I experimented with a current mirror to prevent this, the distortion was almost completely eliminated, but at the expense of two more transistors and more than twice the supply current draw. As this device is powered by a 9V battery and I wanted an extremely simple device I elected to use the simpler output stage. The distortion is quite small at "normal" listening levels and is basically a non-issue.

You might like to use something similar to the audio output stage from the VHF regenerative receiver instead.

The device was built into 250 ml Decor brand Polypropylene kitchen container with a friction-fit lid.

XHTML | CSS | CSS toggle

The circuit was built point-to-point on a sample swatch of Formica (the kind you find in hardware stores), superglue was used to glue down the 3.5 mm stereo headphone jack, the transistors, and several capacitors, giving it sufficient rigidity. The ferrite rod (Jaycar's old short one) friction-fits inside the top of the box surprisingly well. The tuning and regeneration control caps, and the power switch are mounted on the removable lid. The headphone jack and its attached Formica board bolts to the box side, with some foam padding under the board, securing it in place. The 9v battery is simple held in place with a small block of foam when the lid is closed.



Two banana jacks form the external antenna connections, this was done almost as an after though, the radio is more than sensitive enough for local listening with just the loopstick - in fact with an external antenna you may need to modify the AF stage to have a volume control, reducing the regeneration to control the audio volume compromises the selectivity, which is especially important when you have strong signals like an external antenna can give.

The completed radio pulls about 4.5 mA and will work fairly well down to less than 6 volts. Your average 9 V battery should run the radio for 48 hours or more. The supply decoupling networks are mandatory if you want good stability with higher impedance supplies (like flat 9 V batteries!). The biasing of the AF stages can be modified to work virtually right down to 1.5 V, but at much less than 4.5 V and performance of the RF stage drops. It is definitely possible to make the radio run of a single alkaline cell, but two or more are easier to work with.

Usage Experience

The radio really needs a true RF AGC for casual listening. It is a good radio for beginners to build, it is easy to get going, simple and fun. However, compared to an equally simple MK484-based circuit, its very unpleasant to use pedestrian mobile. On foot or on a bus the huge variations in signal strength leave you playing the regeneration control. There is a particular spot on George St Sydney that 2BL 702 kHz absolutely blasts in at (right at World Square). I don't know why, perhaps it has something to do with the height of the world square building, it may be resonant?

The radio is completely unshielded. Mobile phone radiation goes straight through the receiver and blasts you in the ears. Its quite painful when someone calls you and the mobile in your pocket starts actively radiating. I suspect some careful filtering of the headphone line would help a lot. However, I've noticed that the amount of RF noise detected changes as you tune the radio, probably the internal wiring being tuned as the main gang capacitance changes. It is extremely annoying and makes the radio basically unusable on the Ferry in the afternoon were lots of people are calling their partners to arrange dinner, etc.

TV transmitters, CFL and RFL bulbs, naval radars, repeaters, computers, in fact just about everything electronic radiates RF that will get into this radio and be detected if you aren't careful. This is however quite interesting, listening to all this RF smog is instructive, if at times a little deafening.

A little shielding would go a long way. Peter Parker warns against using a metal box, however if I built the radio again I'd definitely use a Aluminium box. The loopstick could be placed outside, in a piece of Aluminium pipe with a slot cut in it to form an electrostatic shield, but not a shorted-turn. Alternatively the entire box could be slotted and the loopstick mounted inside.

7 comments.

Attachments

Circuit Diagram Source	application/postscript	18.045 kbytes

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ARGtek Communication Inc. Limited continually develops the innovative **ARG-2628, 802.11a(5Ghz) 14dBi Double Patch Antenna, 5Ghz, Antenna, Outdoor Antenna, Patch, High Gain, Patch antenna** to meet the various market demands and bring the multiple benefits to customers always. Our products are highly demanded by our clients across the country for optimum quality. In order to ensure longer service life and reliability, our products are manufactured by our vendors using the best quality raw material and latest technology.

802.11a(5Ghz) 14dBi Double Patch Antenna, ARG-2628

Categories > Antenna Series > Outdoor Antenna > 802.11a(5Ghz) 14dBi Double Patch Antenna

Product Name : 802.11a(5Ghz) 14dBi Double Patch Antenna

Description : Dual Patch antenna with attached plastic housing

Features :
·WeatherProof Enclosure
·802.11a hi-Gain patch antenna with housing
·2T2R antenna application

Specification :

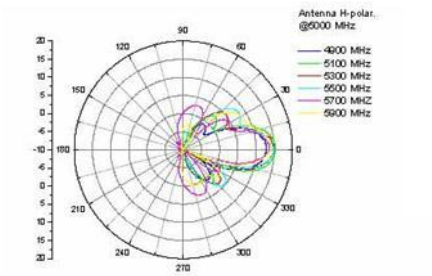
C2614 Patch Antenna (2T / 2R)

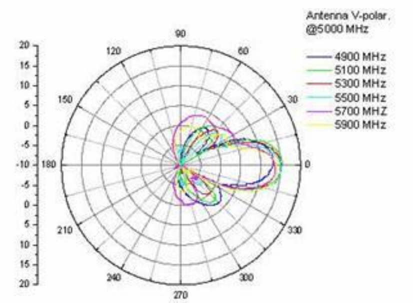
Specifications

Frequency range	4900MHz~5900MHz
Antenna Gain	11n-a/14dBi x 2
Polarization	Linear, vertical
VSWR	2.0 : 1 Max.
HPBW / horizontal	25°
HPBW / vertical	25°
Power handling	2 W (cw)
Impedance	50 Ω
Connector	SMA/Female
Cable	RG316, L=20 cm

Environmental & Mechanical Characteristics

Temperature	-40℃ to + 80℃
Humidity	95% @ 55℃





Package Contents : ＊ 2 pcs of 14 dBi Panel Antenna within case
＊ Mounting Kit

Send Message

* Message :	Dear Sir/Madam, I'm interested in 802.11a(5Ghz) 14dBi Double Patch Antenna, ARG-2628 that your company provides. Would you kindly contact me with your detailed product information and FOB price? Thanks.

Contact Information

* Company Name :

Industry : Please select an industry category

* Contact Person :	
Job Title :	
* Email :	
* Country :	--- Please Select ---
Address :	
* Telephone :	
Fax :	
* Your Product & Service :	
* Check Code :	9749 Change Image

Submit Cancel

ARG-2628 802.11a(5Ghz) 14dBi Double Patch Antenna is one of our main products, featuring its high quality and stylish design. We can manufacture 802.11a(5Ghz) 14dBi Double Patch Antenna that meet specific technical requirements. ARGtek Communication Inc. Limited has tailored our customer service department, product designs, technical support as well as all other company departments to serve the ultimate goal of upholding the highest standards in customer satisfaction. We appreciate the opportunity to attract your attention and value your feedback.

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Taiwan office/factory : sales@argtek.com

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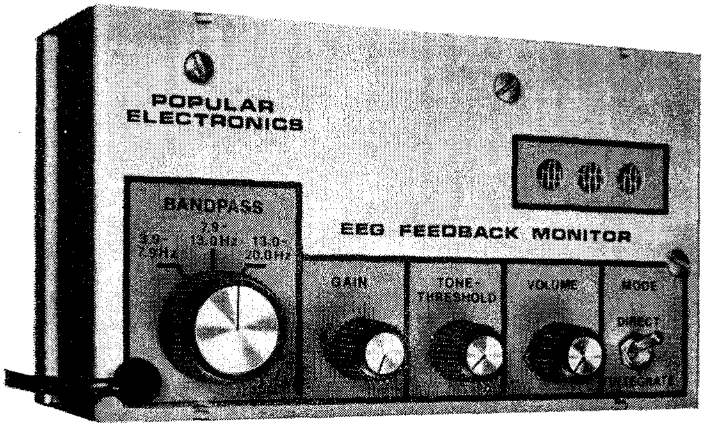


Build an ALPHA BRAIN WAVE FEEDBACK MONITOR

You may be able to learn how to relax through electronics

BY MITCHELL WAITE

THERE is nothing quite so pleasant as being able to relax completely whenever you want to. Unfortunately, today's quick pace rarely leaves us the time to truly relax.

Perhaps for that reason, scientists have come up with an electronic approach to relaxation that might revolutionize the art of "calming down." Drawing on knowledge of general psychology, eastern meditation techniques, and, in particular, clinical electroencephalography, researchers in the field of alpha-wave feedback have progressed rapidly in the last few years and made many significant gains.

Unlike the older forms of meditation, alpha-wave feedback requires neither an avatar or guru. Researchers have found that the minute brain-wave frequency band between 7.5 and 13 Hz is continuously produced in meditative stages of Yoga and Zen. This is called the "alpha state." The assumption is that the length and intensity of alpha-wave production is an impartial measurement of the ability to reach a special state of "relaxed awareness," found in certain types of meditation.

People who produce continuous alpha seem to experience a generally heightened sense of well-being, with a parallel increase in clarity. Thus, alpha feedback allows one to prepare for demanding mental tasks by previously clearing the mind of distracting thoughts and ideas. It is precisely for this reason that some businesses are investigating alpha feedback. Researchers are also suggesting that the "pain" of education can be lessened if these procedures are used in attention control. There is the possibility, they say, that recall can be improved and mental blocks avoided during examinations, by the use of alpha feedback.

Basic Approach. In alpha feedback, high-gain, low-noise amplifiers detect the microvolt signals of the brain and use them to modulate a sound or other stimulus. The person training for increased alpha completes the feedback loop by listening to the rise and fall of a tone as the brain waves come and go. Thus, by learning to produce just the elusive 7.5-to-13-Hz modulation, a person can experience the alpha state.

Actually, all brain waves have charac-

teristic mental correlates. For example, deep sleep produces the long slow waves between 2 and 4 Hz; problem solving and daydreaming give rise to the theta rhythms (3.5 to 7.5 Hz); while tension, worry, or surprise produce the beta frequencies (13 to 28 Hz). There is also evidence that creative and spontaneous moods occur most often when the frequencies between alpha and theta are active. This has led some researchers to speculate that creativity and insight might be facilitated by learning how to increase frequencies.

The important thing is to find out more of all this for yourself. With the circuit described, you may be able to influence and enjoy all of the brain-wave states. In addition, the project can be used to listen to such body signals as scalp tension and heart rate.

About the Circuit. Because of the rapid increase in the popularity of biofeedback, a large selection of feedback monitors have appeared on the market. Their complexity ranges from a device for alpha feedback using only one IC to research laboratory equipment costing thousands of dollars. The latter include such features as strip chart recorders, multi-channel amplifiers, highly controllable filters, percent time indicators, etc.

The circuit shown in Fig. 1 incorporates functions usually found only in more sophisticated equipment. For example: because the different brain waves are very close in frequency, a switchable 4-pole bandpass filter is used. Each filter is tuned to the center frequency of the theta, alpha, and beta bands. These filters obviously make recognition of a particular brain wave much easier and faster.

Another critical parameter of a feedback machine is its ability to reject strong common-mode interference—such as 60-Hz hum or erroneous signals from electrode movement—while presenting a high input impedance. An inexpensive solution to this problem is to use a single low-noise op amp in the differential mode. This solution is not completely satisfactory because of the inevitable tradeoff between input impedance, balance, and common mode rejection. Here we use an instrumentation amplifier for the front end, with two low-bias op amps (*IC1* and *IC2*) providing an almost infinite input impedance and excellent common mode rejection.

Electrodes, which couple the microvolt signals to the amplifier, are critical in two respects. They should not generate short-term voltages (tiny noise spikes) or long-term voltages (offset or drift). A number of low-cost commercial machines use an inert material such as stainless steel for electrodes. The difficulty with these electrodes is that they produce some noise spikes and (more seriously) generate a slow voltage offset, which (if the input stage is direct coupled) can eventually saturate the output. A better approach is found in laboratory applications where silver electrodes coated with a layer of chloride are used. Though these electrodes are free of noise and have no long-term voltage drifts, the chloride surface must eventually be replaced so the electrodes are disposable types. However, with proper cleaning, they will last for some time. The least troublesome approach is to use pellet-type Ag/Ag-C1 electrodes which, due to their special construction, last indefinitely.

Another more general consideration in designing an EEG monitor is the type of modulation used to produce the audio feedback. Most models use the amplified, filtered brain wave either to amplitude- or frequency-modulate a fixed tone. In the monitor described here, a unique combination tone-threshold control can be adjusted to produce either AM, FM, or a combination of the two.

It is also necessary to determine what aspects of the brain-wave envelope shall vary the tone. The two most common methods use either a direct or integrated waveform to modulate the audio. With the mode selector switch, S2, in the DIRECT position, the instantaneous waveform passing through the filter frequency modulates an adjustable tone. This mode creates an effect in which one seems to be tuning directly to the thought of the brain. If the continuous tone is objectionable, the oscillator can be set just below its threshold point so that only the peaks of the filtered waveform trigger the tone. The latter method integrates the filtered waveform over a fixed period of time.

In this monitor, depending on the setting of the threshold control (*R42*), the tone can be made absent when no signal is present. When the threshold is exceeded, the frequency of the tone is proportional to the envelope of the signals. This mode is better for biofeedback training since the

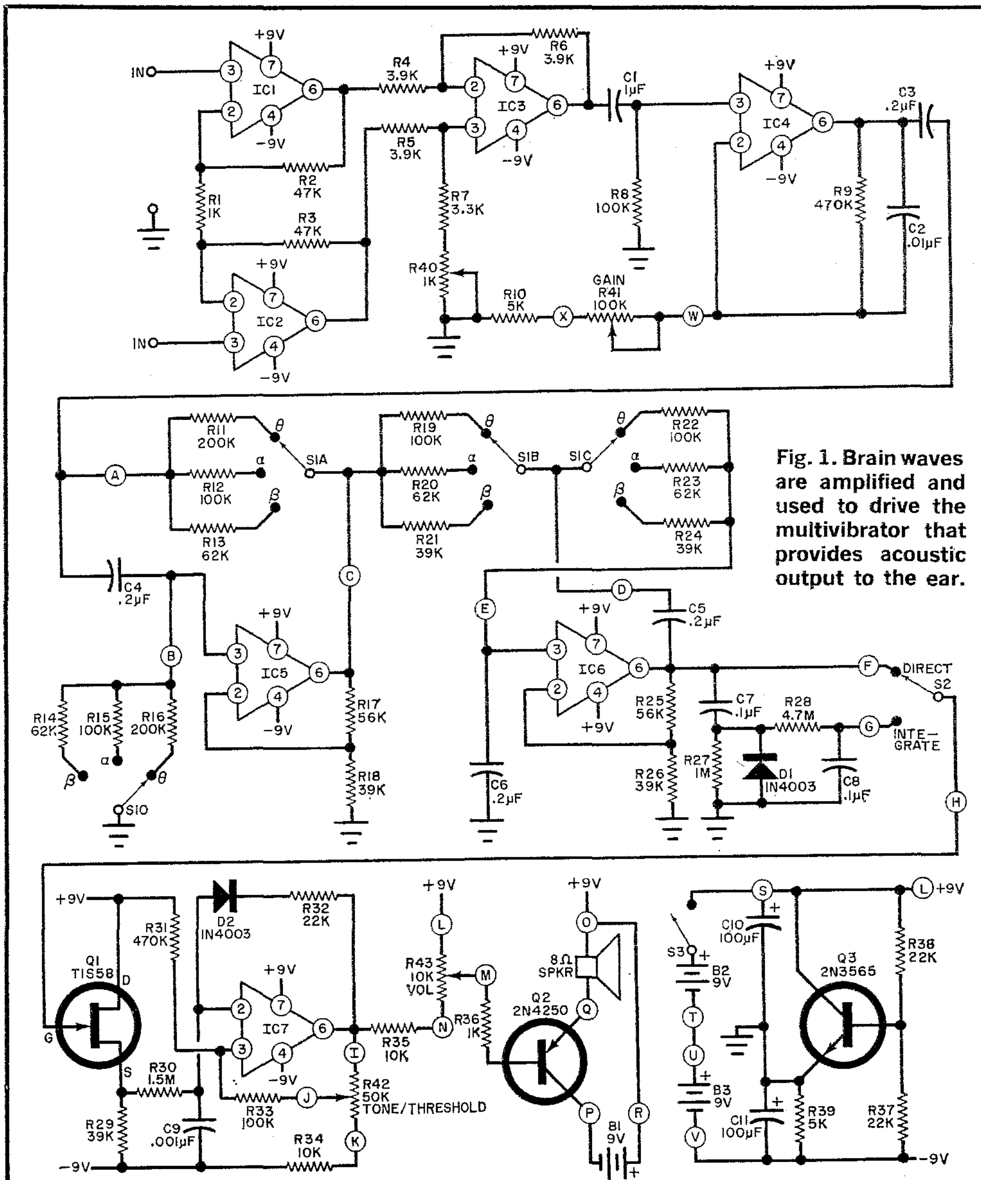
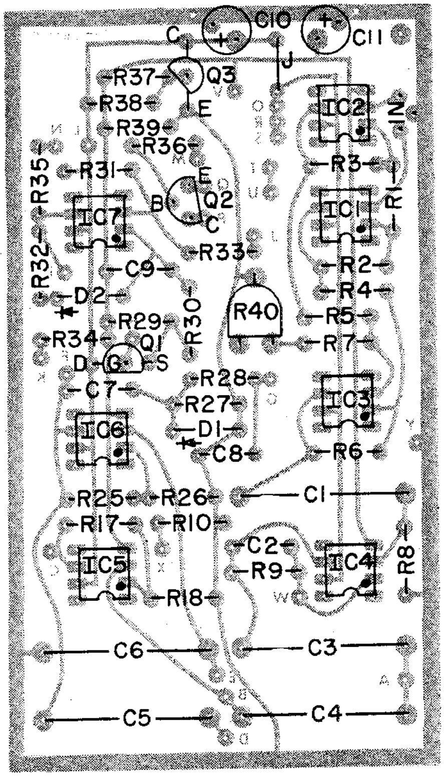


Fig. 1. Brain waves are amplified and used to drive the multivibrator that provides acoustic output to the ear.

PARTS LIST

B1,B2,B3,—9-volt battery
C1—1-µF, 10% Mylar capacitor
C2—0.01-µF disc capacitor
C3-C6—0.2-µF, 10% Mylar capacitor
C7,C8—0.1-µF, 10% Mylar capacitor
C9—0.001-µF, 10% Mylar capacitor
C10,C11—100-µF, 2-volt electrolytic capacitor
D1,D2—1N4003 silicon diode
IC1,IC2—N5556 op amp (Signetics, do not substitute)
IC3-IC7—741 op amp
Q1—TIS58 field effect transistor
Q2—2N4250 transistor
Q3—2N3565 transistor
R1,R36—1000-ohm, ¼-watt, 5% resistor
R2,R3—47,000-ohm, ¼-watt, 5% resistor
R4-R6—3900-ohm, ¼-watt, 5% resistor
R7—3300-ohm, ¼-watt, 5% resistor
R8,R12,R15,R19,R22,R33—100,000-ohm, ¼-watt 5% resistor
R9,R31—470,000-ohm, ¼-watt, 5% resistor
R10,R39—5000-ohm, ¼-watt, 5% resistor
R11,R16—200,000-ohm, ¼-watt, 5% resistor
R13,R14,R20,R23—62,000-ohm, ¼-watt, 5% resistor
R17,R25—56,000-ohm, ¼-watt, 5% resistor
R18,R21,R24,R26,R29—39,000-ohm, ¼-watt, 5% resistor
R27—1-megohm, ¼-watt, 5% resistor
R28—4.7-megohm, ¼-watt, 5% resistor
R30—1.5-megohm, ¼-watt, 5% resistor



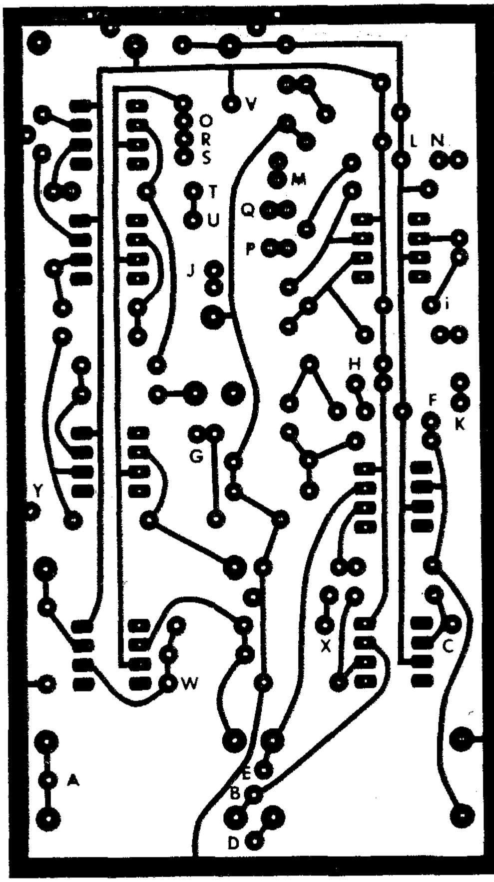


Fig. 2. Actual size foil pattern is at right with component layout above.

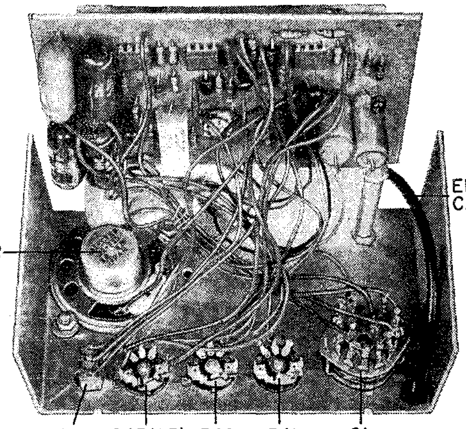
tone gives a direct indication of the desired result.

This monitor also has an audio amplifier with speaker and volume control (*R43*), so that a group can listen or the volume can be reduced to a quiet level.

How It Works. Integrated circuit *IC1* and *IC2* amplify the differential signal between the two input leads while providing unity gain for the common mode signal. The residual common mode signal is removed by *IC3* and can be nulled to zero by trimmer *R40*. The signal is then coupled through *C1* to *IC4* and further amplified. The gain of this stage can be varied from about 5 to 95 by the setting of *R41*.

Integrated circuit *IC5* forms a two-pole

R32,R37,R38—22,000-ohm, ¼-watt, 5% resistor
R34,R35—10,000-ohm, ¼-watt, 5% resistor
R40—1000-ohm trimmer potentiometer (PC type)
R41—100,000-ohm miniature potentiometer
R42—50,000-ohm miniature potentiometer
R43—10,000-ohm miniature potentiometer with attached switch for S3
S1—4-pole, 3-position shorting rotary switch
S2—Spdt switch
S3—Spst switch on R43
SPKR—Miniature 8-ohm speaker
Misc.—Four feet of 2-conductor shielded flexible cable, metal enclosure, battery connectors (3), knobs (4), rubber grommet, headband, electrode cream, electrodes, earclip, mounting hardware.
Note—The following are available (postpaid, but insurance extra) from Extended Digital Concepts, Box 9161, Berkeley, CA 94709: #PE2, etched and drilled PC board at $4.49; #PE3, IC1 and IC2 at $6.49; #PE4, set of stainless steel electrodes at $1.49; set of disposable Ag/Ag-Cl electrodes at $3.49; #PE6, set of reusable Ag/Ag-Cl electrodes at $14.95; #PE1, complete kit of parts including sets of disposable and stainless steel electrodes, drilled and etched board, drilled and painted enclosure, elastic headband, electrode cream, and earclip at $58.95. California residents, add 5% sales tax.



Photograph of prototype shows how components were assembled in box.

active filter which rejects signals lower than the frequency determined by capacitors $C3$ and $C4$ and $R11$ through $R16$. Conversely, $IC6$ removes signals higher than its selected frequency. The net effect is a filter which passes only a narrow band of low frequencies.

With $D1$ as a shunt rectifier and $C8$ and $R28$ as a smoothing filter, the signal is passed to $Q1$, a FET operating as a source follower with unity gain. Integrated circuit $IC7$ is connected in a multivibrator circuit and is normally saturated with the output voltage near the positive supply voltage. When $C9$ charges through $R30$ to a voltage higher than the level provided by the voltage divider made up of $R31$, $R33$, $R42$, and $R34$, $IC7$ saturates due to positive feedback. Capacitor $C9$ then discharges through $D2$ until $IC7$ flips back to its previous state. The signal from $Q1$ varies the charge on $C9$ and thus modulates the tone.

Transistor $Q2$ is a source follower which provides a low impedance to drive the speaker without overloading the multivibrator. A separate battery ($B1$) is used for the speaker to avoid feedback.

Transistor $Q3$ is a source follower which creates a low-impedance ground about half way between the plus and minus supply voltages. This also permits the use of a single-pole switch ($S3$) to turn the monitor on and off. It is not necessary to disconnect $B1$ because its drain is negligible with S3 open.

Construction. The use of a PC board (foil pattern shown in Fig. 2) makes construction easy. Mount the components as shown, observing the notch and dot code of the IC's. Also make sure that the two diodes and three transistors are properly installed. The lettered terminals correspond to those on the schematic. The resistors associated with $S1$ are connected directly to the terminals on the switch. Use fine solder and a low-power soldering iron.

The circuit board and batteries can be installed in any small enclosure. The three potentiometers ($R41$, $R42$, and $R43$) and the two switches ($S1$ and $S2$) should be mounted on the front panel, with a small grommeted hole also on the front panel for the shielded cable. The speaker is cemented to the front panel with a few holes drilled in the panel for the sound to come through.

Prepare the electrode cable by removing about 12″ of the outer insulation from the cable. Unwind the shield and twist it into cable form. Solder this shield lead to the earclip. Remove about ½″ of insulation from the two insulated leads and carefully solder them to the electrodes. When soldering to stainless steel, first lightly sand the metal surface with fine sandpaper.

Testing. Install fresh batteries, turn the circuit on, and adjust the tone/threshold control ($R42$) until a tone is heard in the speaker. Set the bandpass switch ($S1$) to its lowest range (3.9-7.9 Hz) and the mode control ($S2$) to direct. Using a small amount of electrode cream, clip the ground lead to an earlobe. Saturate the electrodes with cream, and steadily hold one electrode in each hand. The circuit should pick up your heartbeat, amplify it, and send it through the speaker. This is a noticeable beep, about one a second. The pulse signal is about 1 millivolt (10 times greater than alpha-wave level) so turn the gain control down. If you cannot hear your pulse, check the wiring.

If you have a signal generator and scope, the circuit may be further analyzed by clipping one input and the ground lead to the signal generator ground and feeding an attenuated signal into the other input lead.

The dc output of all op amps should be near zero.

Balancing the Amplifier. Potentiometer *R40* is used to trim the gain of one side of the differential amplifier to make both gains exactly the same. When they are equal, common mode rejection is maximum. The best procedure is to feed a common mode signal of 3 to 4 volts into both inputs tied together, across a 10,000-ohm resistor. Put a scope or ac VTVM on the output of *IC4* and adjust *R40* for the smallest signal. If you do not have a scope or signal generator, hook the electrodes through the 10,000-ohm resistor to ground and touch the common leads. You will hear 60-Hz noise from your body. Adjust *R40* for minimum noise or the clearest tone.

Use of the Monitor. First, a note of caution. The monitor, like most commercial machines of this type, is battery operated. This is to prevent a shock in the rare event that the 60-Hz power line shorts to the inputs. Therefore, for complete safety, avoid hooking the monitor to any ac-operated equipment such as scopes, battery eliminators, etc. When ac devices are hooked up to an EEG monitor in a laboratory, light coupling devices or fused fail-safe systems are used.

If you are sure the monitor is picking up EKG and properly balanced, you are ready to try EEG feedback. Place a small bit of electrode cream on the earclip and attach it to either earlobe. Wrap an elastic or soft cloth band around the head, aligned so that it is over the eyebrows and at the widest part at the back of the head. Pin the cloth to hold it on. Put a small amount of cream on each electrode and place one under the band just above the left or right eyebrow. Place the other in line with the first at the rear of the head. Spread the hair apart and add a little more cream. The electrodes will function best when they float above the scalp with electrode cream bridging the gap. With the electrodes placed in this manner, you should be picking up mostly what is called occipital alpha. In more advanced stages of meditation, alpha production increases in the frontal areas of the brain. You can experiment with this by placing both leads on the forehead.

Sit or lie down in a quiet, comfortable place. Turn the monitor on, place the bandpass switch in the alpha range (7.9-13.0 Hz), with mode in DIRECT, turn the gain all the way down, and adjust the tone and volume to a pleasing level. Blink your eyes and listen for a beep. Slowly turn the gain up. If the electrodes are correctly placed, no hum will be heard. Now, with the eyes open and focused on an object, adjust the gain for a fairly steady tone. Because you are producing mostly beta and the bandpass is on alpha, you should not hear the beta frequencies. Now close the eyes and listen for a rhythmic modulation of the tone. Do not *try* to produce this rhythm; let the mind go and just listen for it. The occasional fluttering of the tone will be the alpha waves.

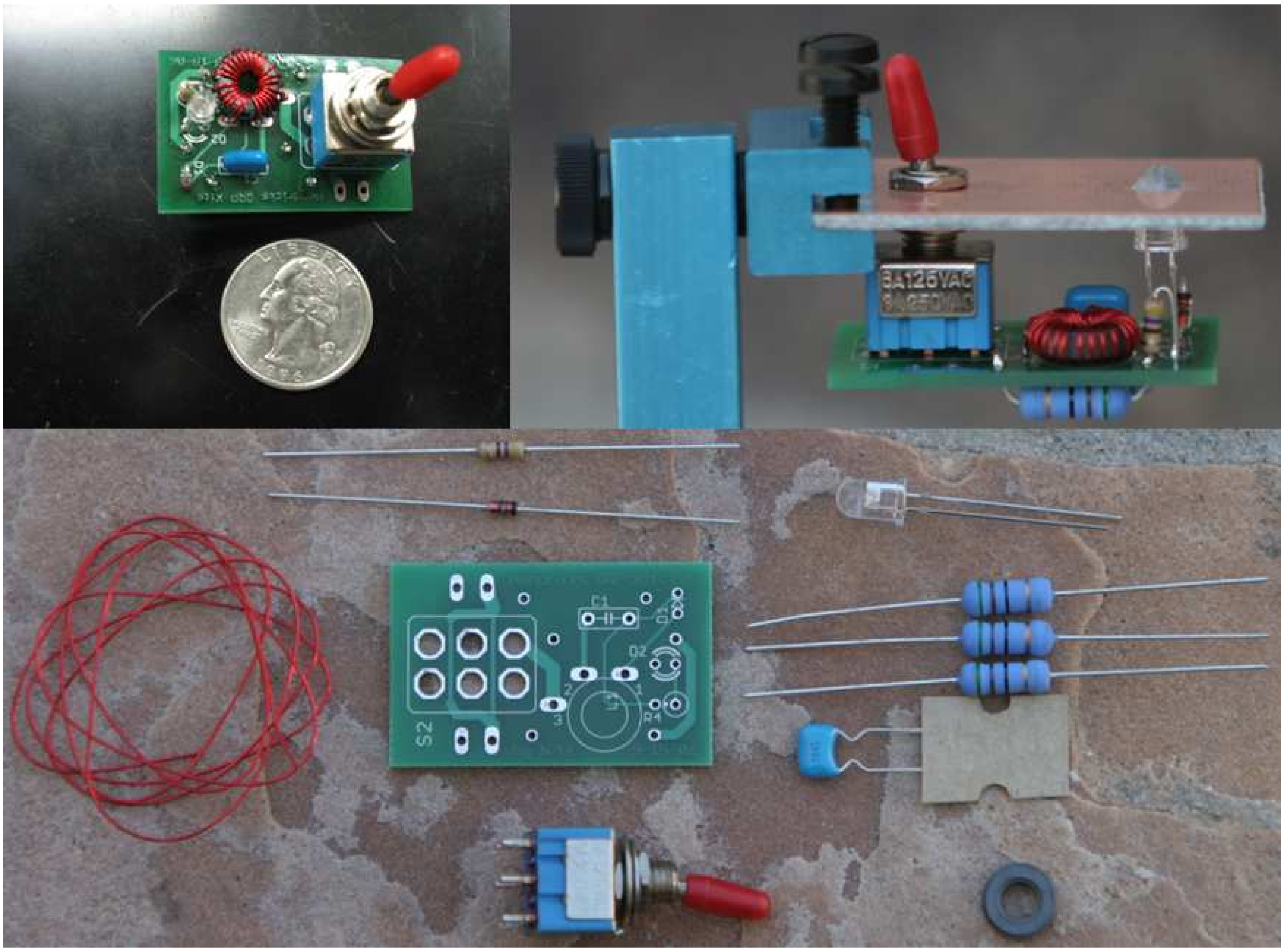
Notice the types of thoughts that block the alpha. After you are sure you are producing alpha, switch S2 to INTEGRATE and adjust the threshold/tone control so that, when the eyes are open, there is no tone. Shut the eyes and practice increasing the number of times the tone is on (percent time training). Later try increasing the frequency of the tone (amplitude training).

In laboratory training, a usual alpha session lasts 10 to 15 minutes a day for about two weeks. If you stick to it, you may eventually notice a feeling of well-being and relaxation after each session. To experiment with the other brain-wave bands, simply repeat the procedure with the filter switched to the desired band. Try lowering the dominant alpha frequency toward theta in the direct mode and notice if spontaneous thoughts or ideas come more easily.

When you have finished using the monitor, carefully wipe the cream off the electrodes. If you are using stainless steel electrodes, sand them lightly and clean them with alcohol.

One final note: alpha-wave feedback has produced results similar to meditation, but it works much faster. It is still, however, a subtle effect and requires diligence and experimentation to obtain worthwhile results. ◈

Editor's Note: This article, which follows last month's story on principles of biofeedback training, describes an easily constructed project for experimentation. There have been many claims made for brain-wave monitors —some highly exaggerated. We make no such claims, other than that the circuit operates properly.



N7VE LED SWR Bridge

Hendricks QRP Kits

A simple, rugged and lightweight SWR bridge

by Dan Tayloe, N7VE

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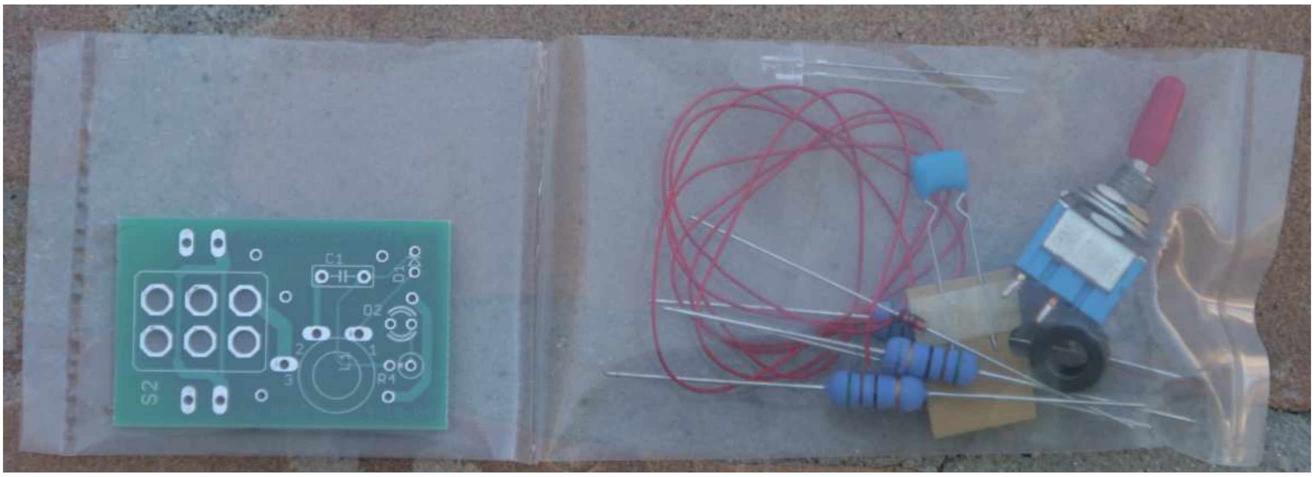

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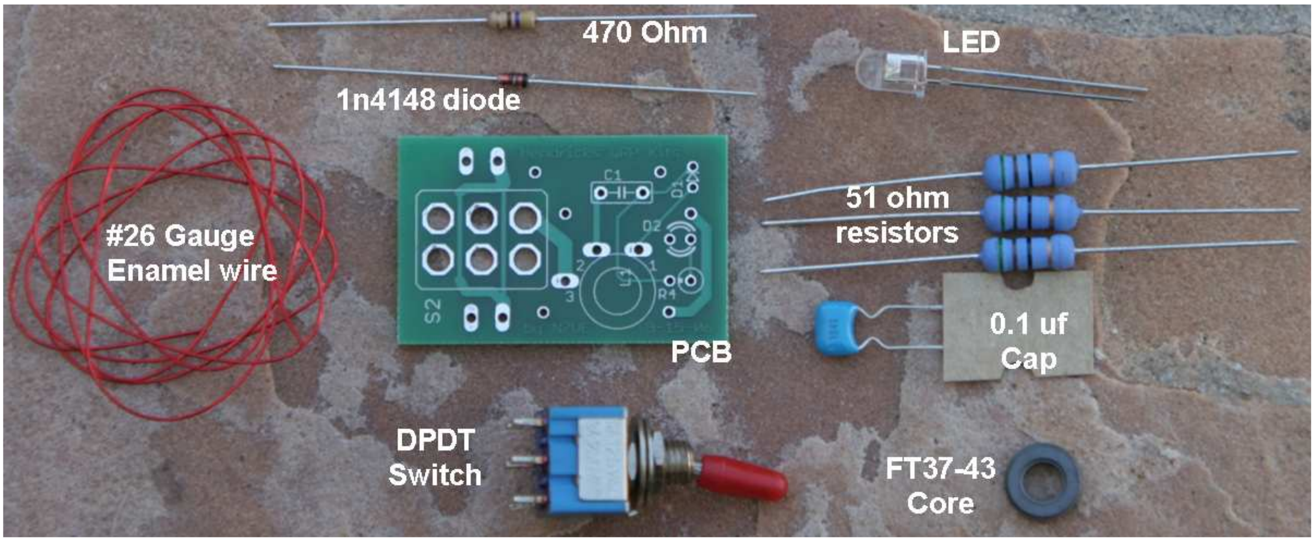

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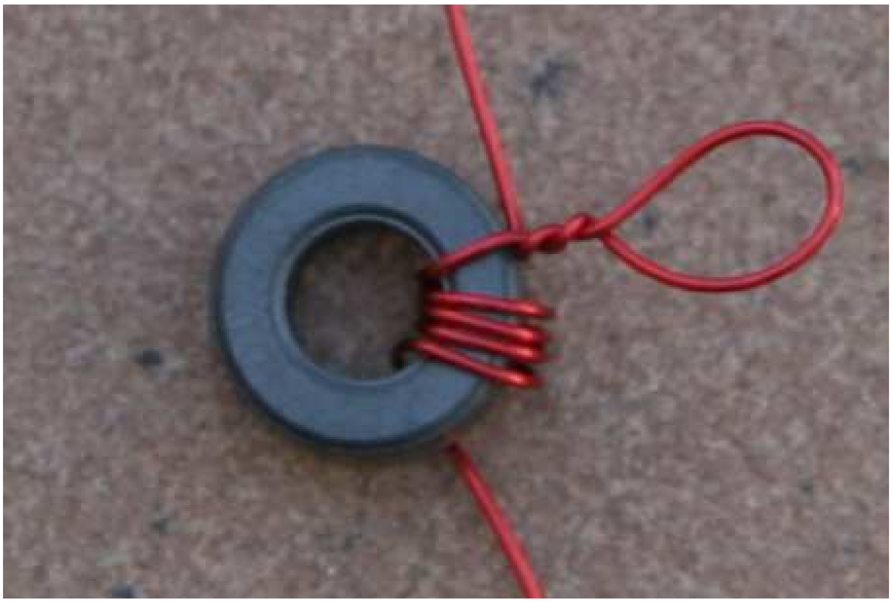
Note: Order is important: LED last; Switch next to last, 51 ohm power resistors just before that.

Note: This bridge is for QRP only! 5w average power (10w PEP) max!

RF step up transformer



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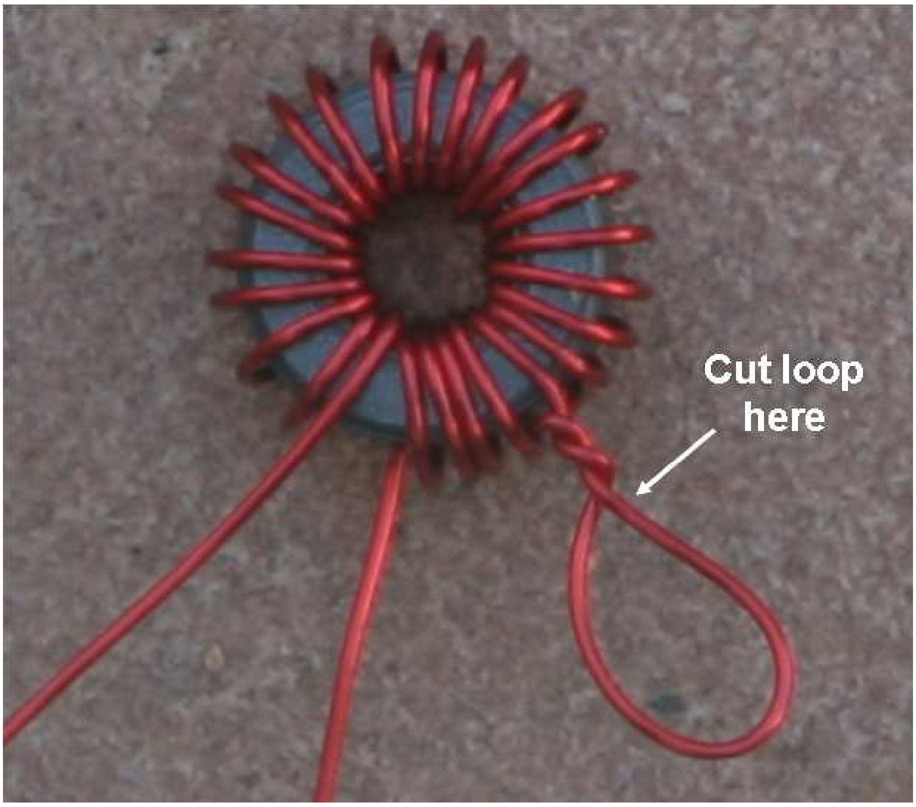

Figure 4. 25 turns total totally fills the core.

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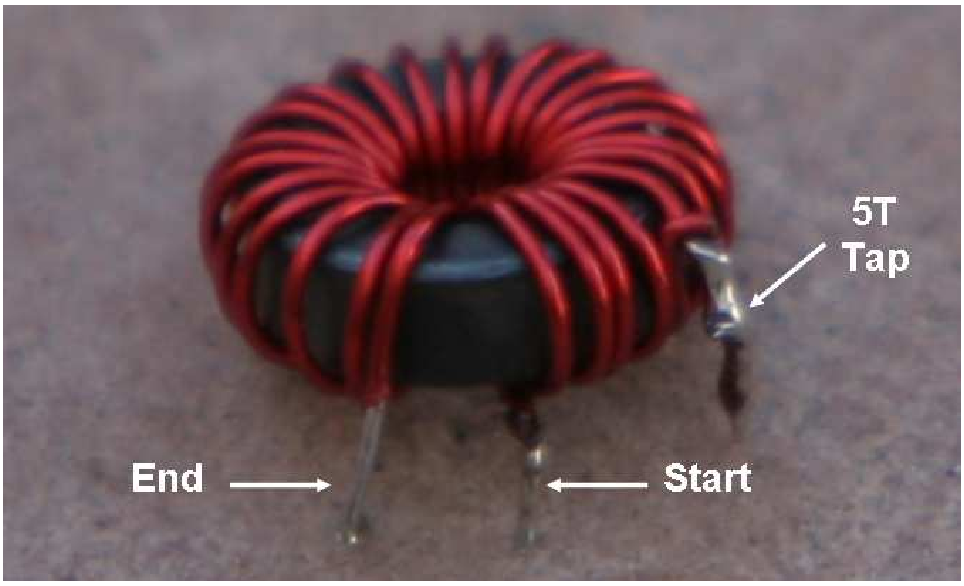
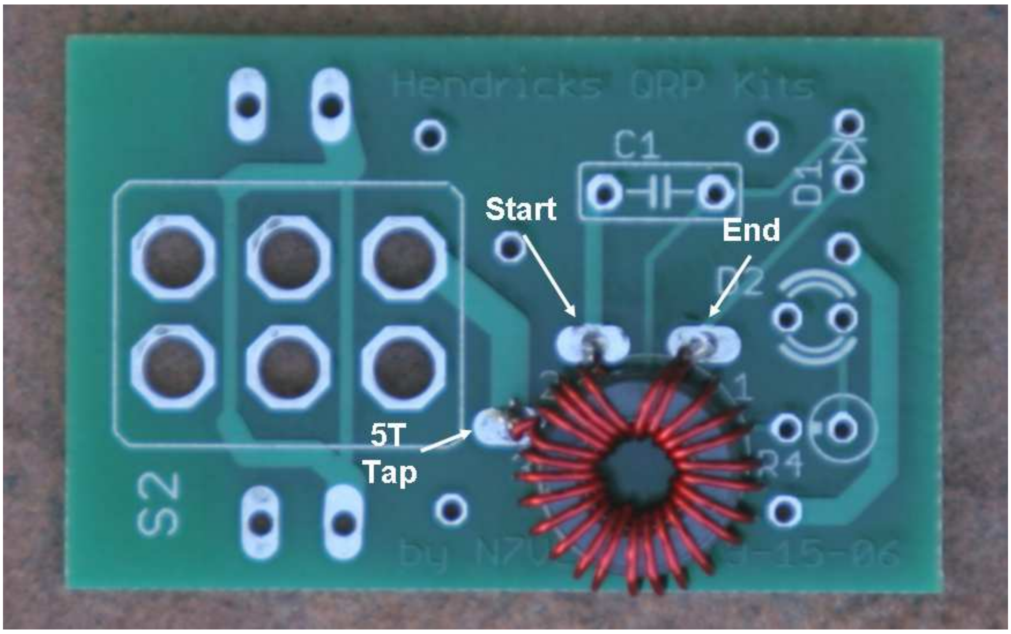


Figure 5. Close up view of the RF step up transformer with dressed leads

After dressing the leads as above, take an ohm-meter, place it across the "start" and "end" leads above, and make sure that the ohm-meter shows a short (0 ohms). If this is not the case, the twisted leads at the 5T tap have not been properly soldered together.



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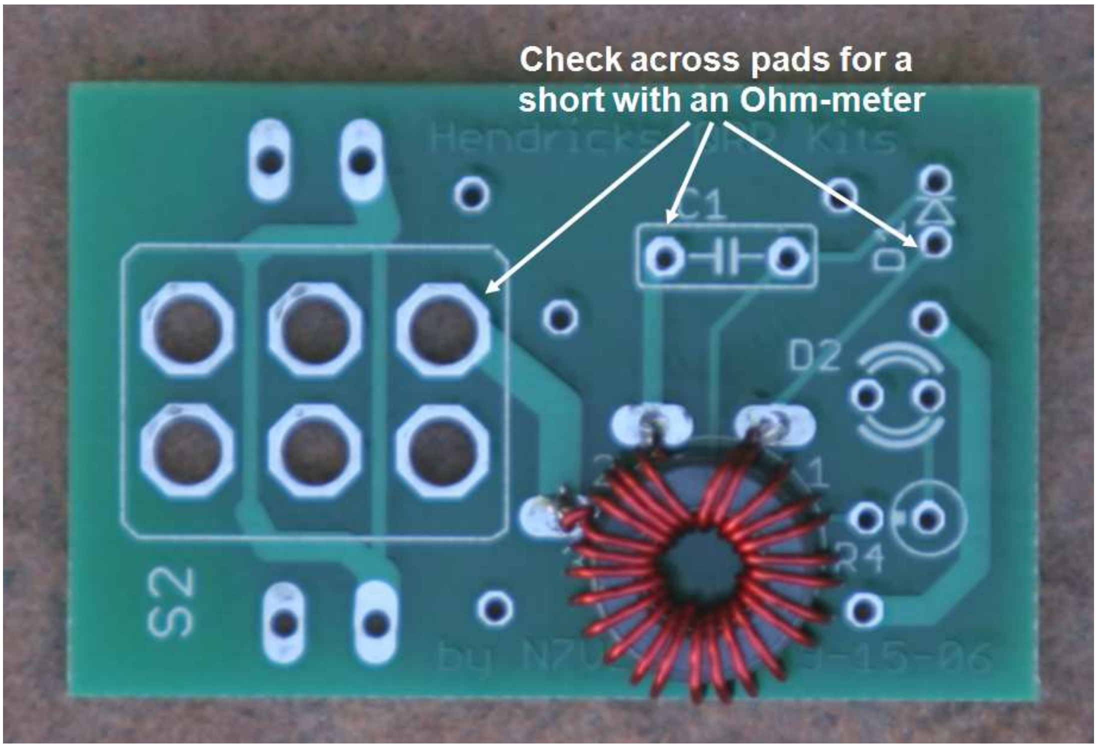
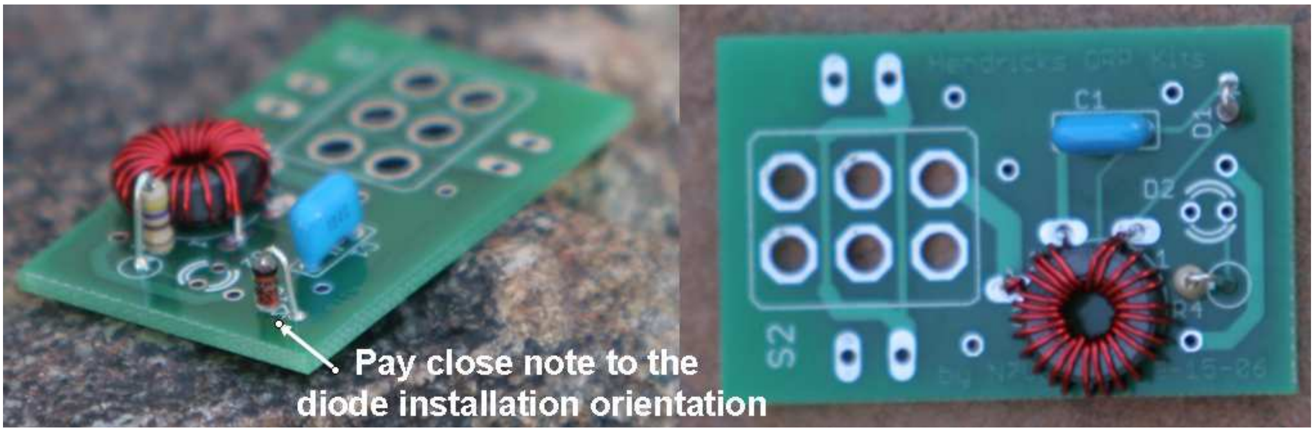


Figure 7. Double check after mounting that the inductor is mounted properly. These pads must be shorted!

Using a ohm-meter check the three pads above to make sure that all of these pads show a short to each other. This makes sure that the RF step up transformer has been constructed and mounted properly.

Other top mounted parts



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C1 has some crimps that I straightened out in order to mount it more flush to the top of the board as shown. R4 gets mounted now also

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The LED does not get mounted until the very last step! Do not mount the switch yet!

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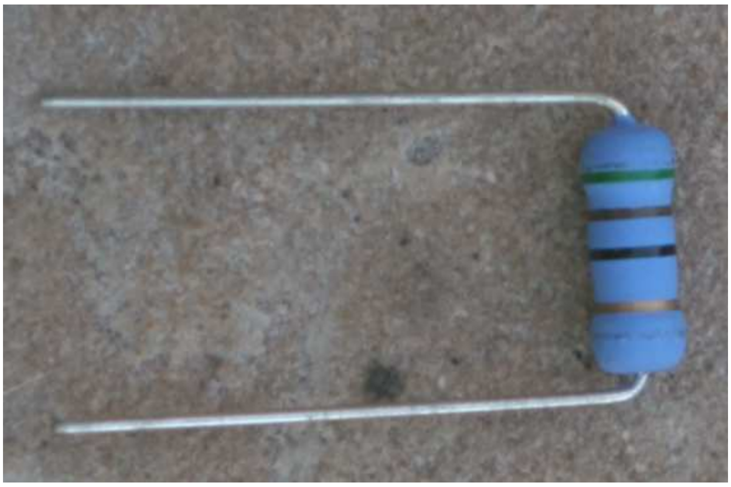

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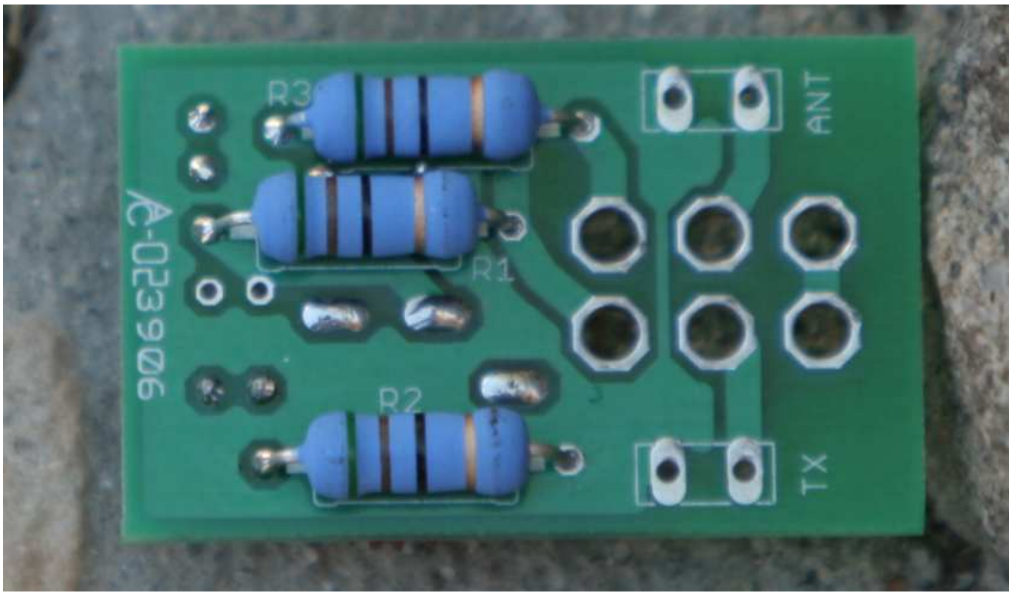

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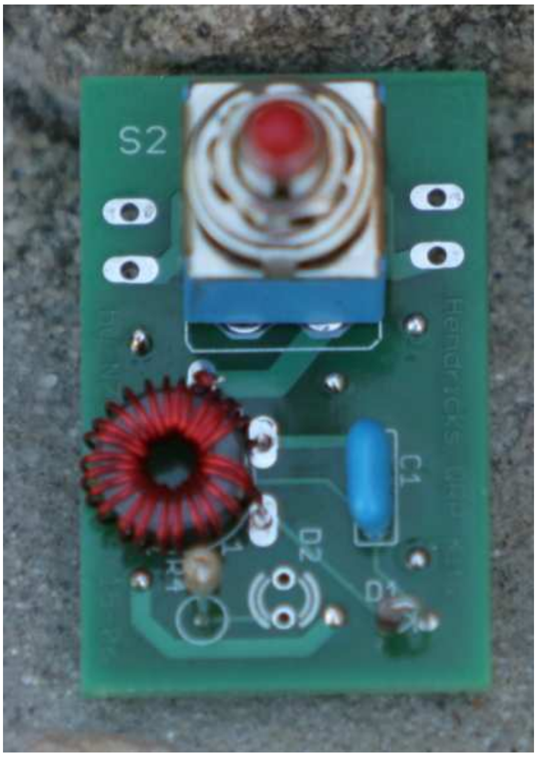
DPDT Switch mounted



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It is a bit hard to keep the switch flat while soldering it down. I suggest soldering down one corner, making sure the switch is flat, then soldering the opposite corner, and double checking the switch is indeed flat and level before finally soldering it down.

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Mounting the board to a case

Attaching the switch to the case

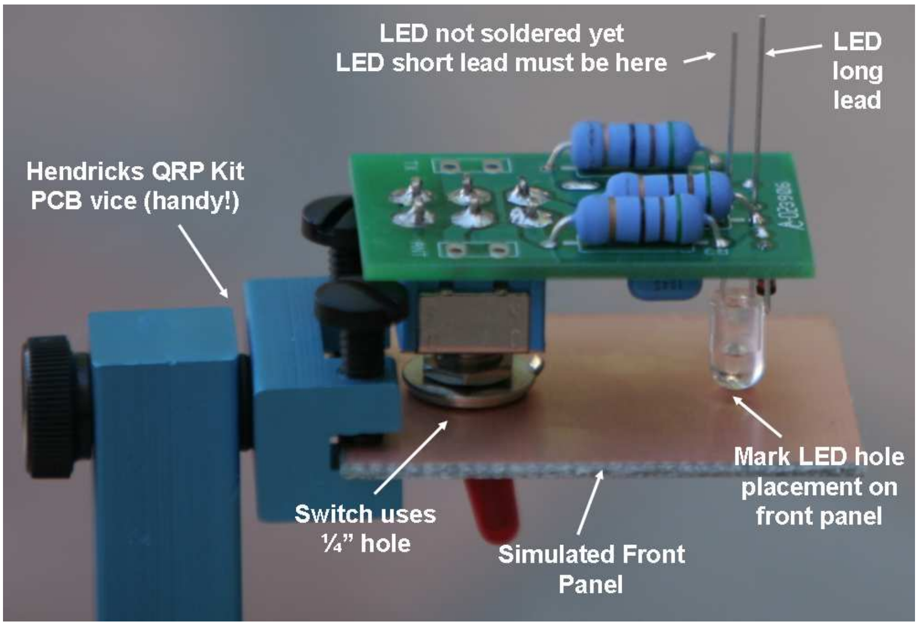
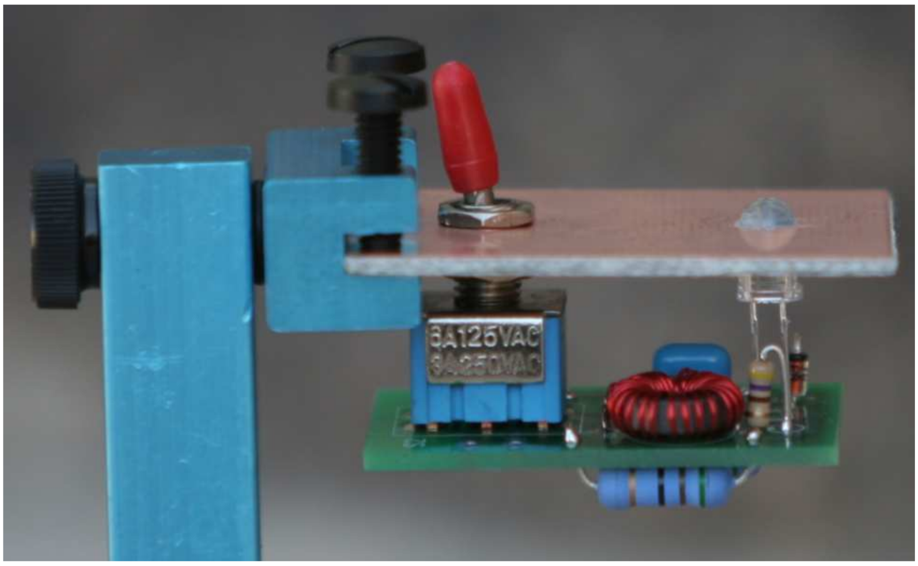


Figure 12. Switch mounted to simulated front panel. LED not soldered yet.



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The LED shown here is larger than that actually supplied. I personally like the smaller one better. I drilled LED the hole slightly smaller than the LED, then gradually enlarged the LED hole by spinning a tapered file in it until I got a snug press fit of the LED in its hole. Alternative epoxy could be used.

Initial DC tests

Place an ohm-meter across the terminals market "**TX**". With the toggle handle ***away*** from the LED (as shown in the figure above), the ohm-meter should show 75 ohms. In this position, the SWR bridge is ***in*** the circuit, allowing SWR readings to be taken.

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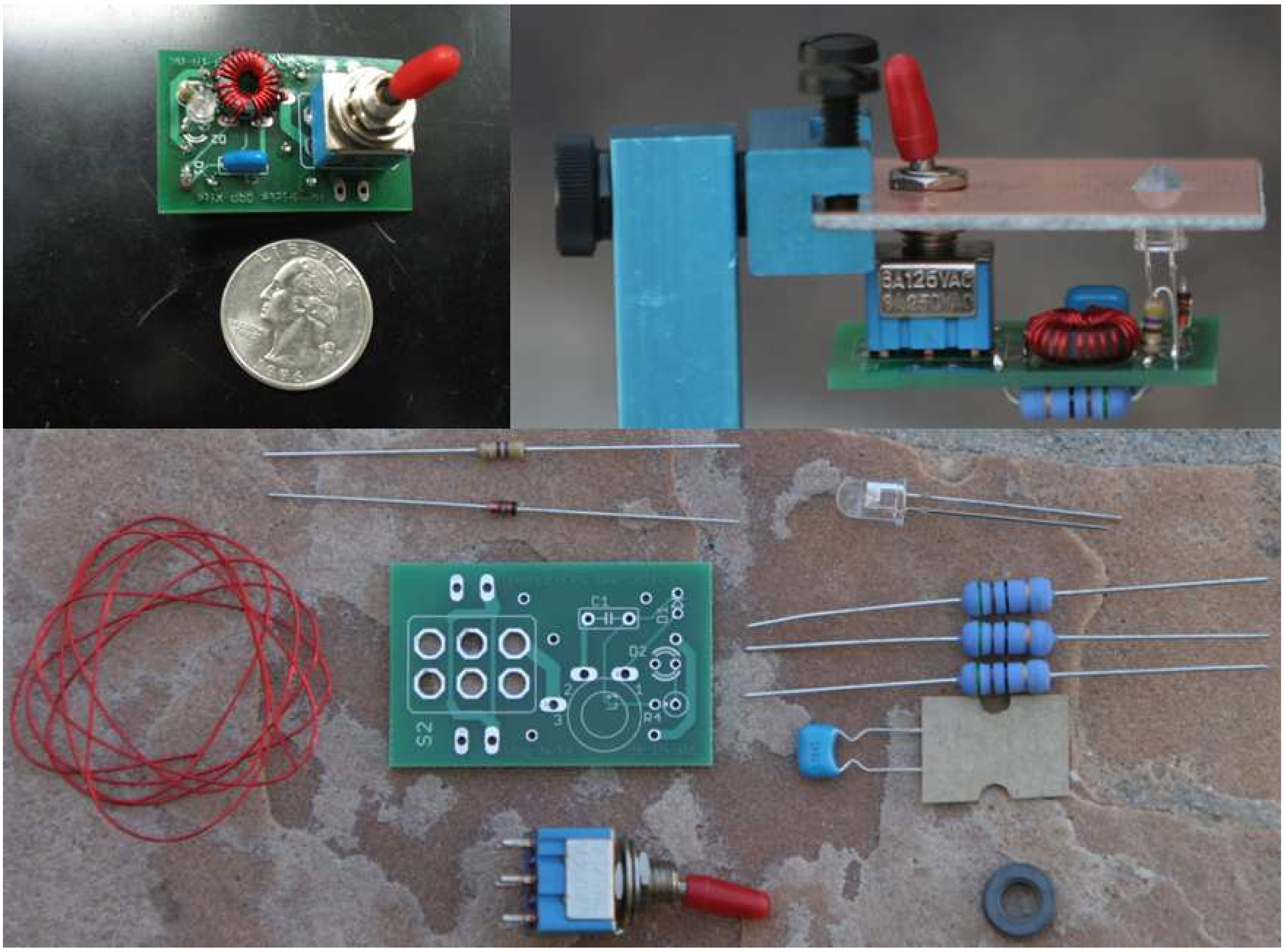

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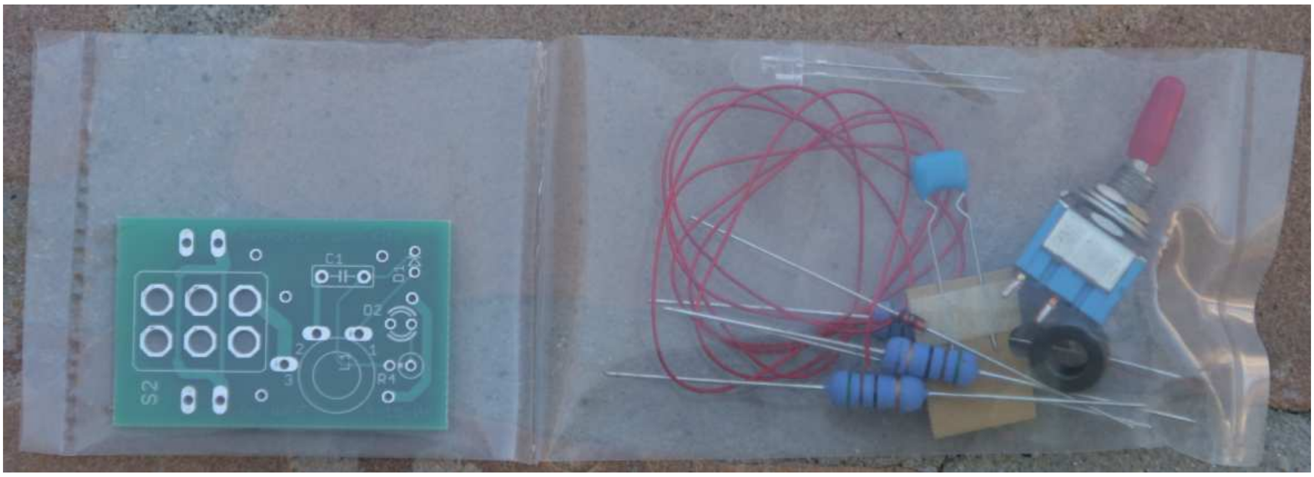

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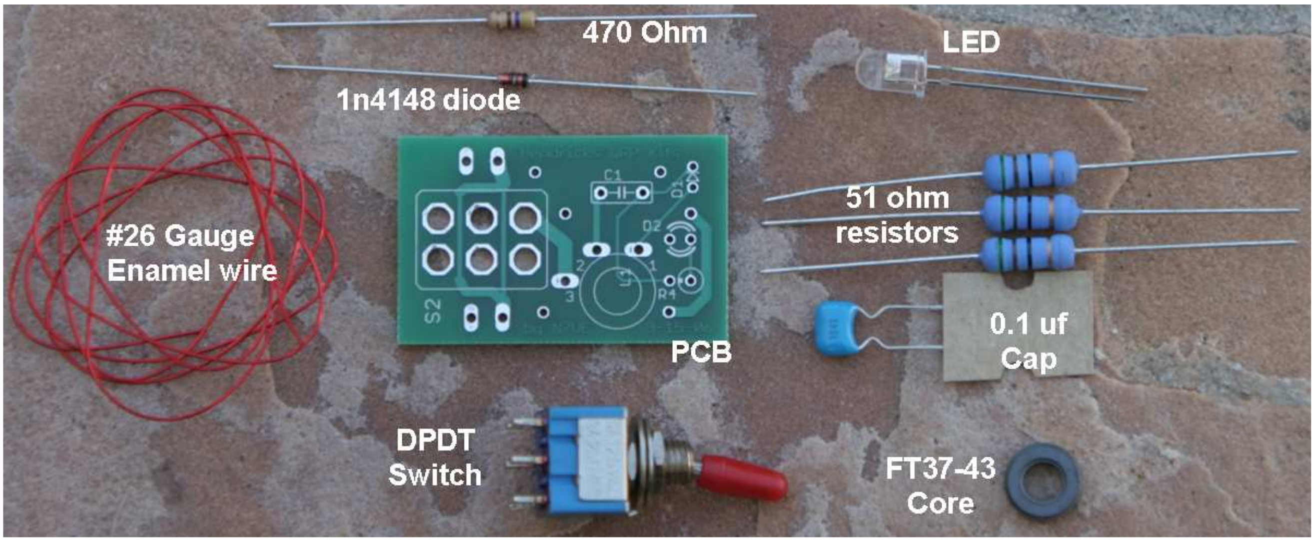

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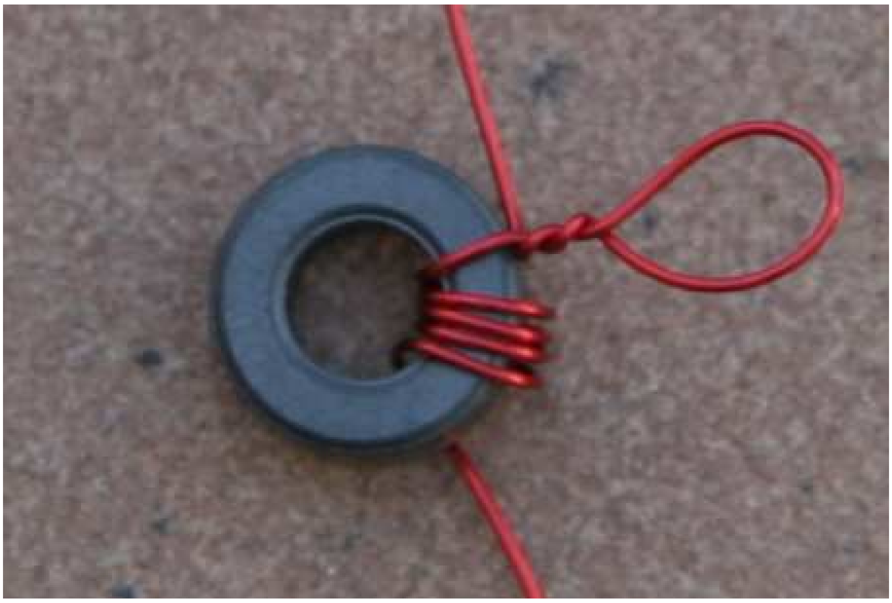

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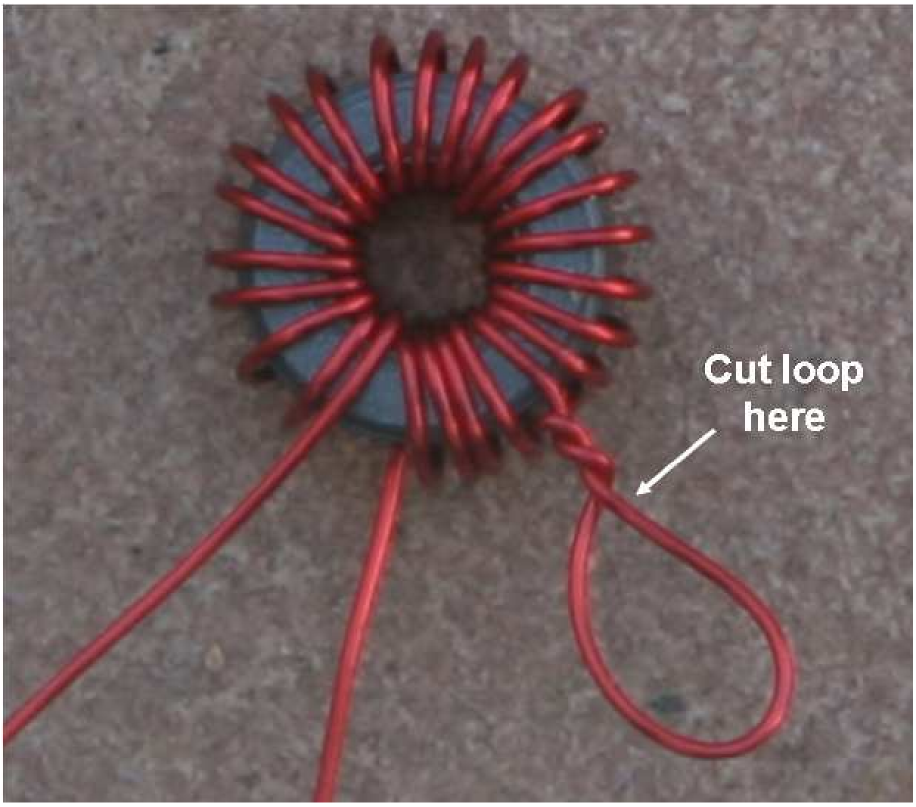

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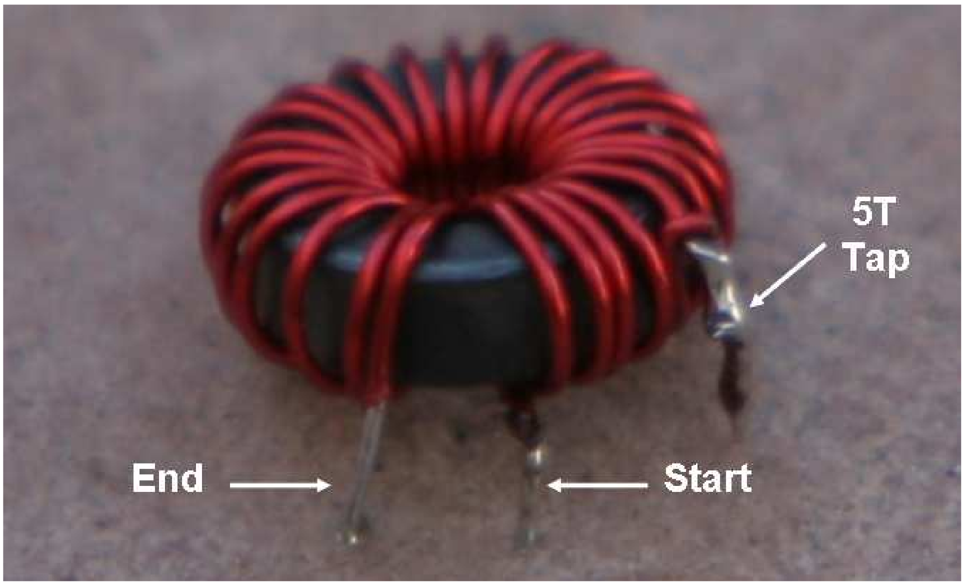

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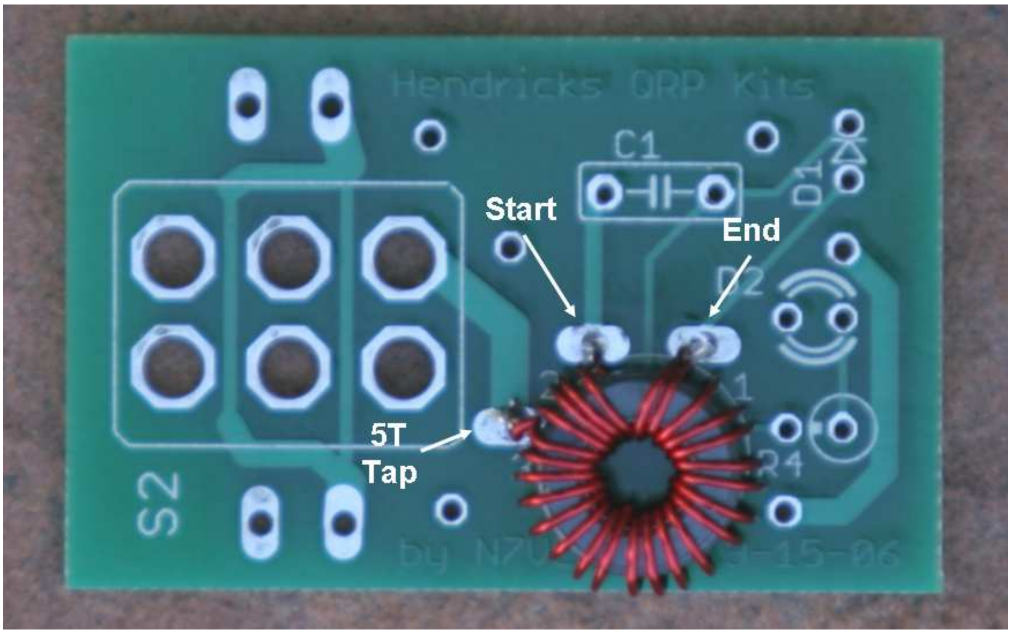

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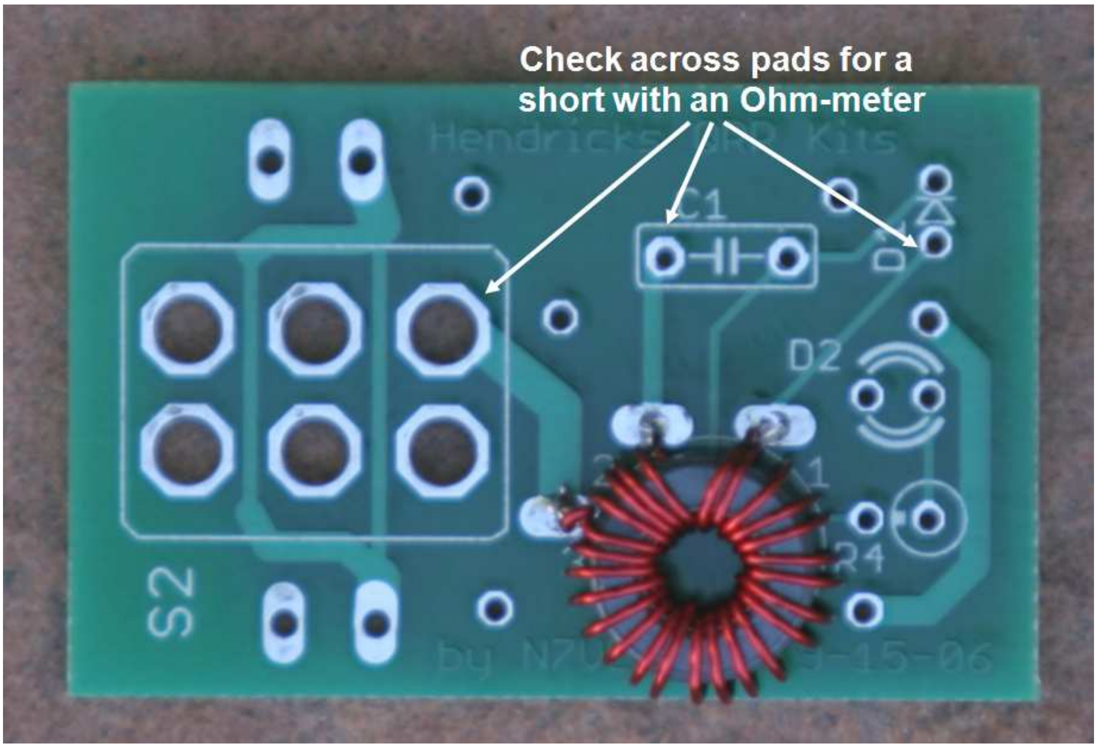

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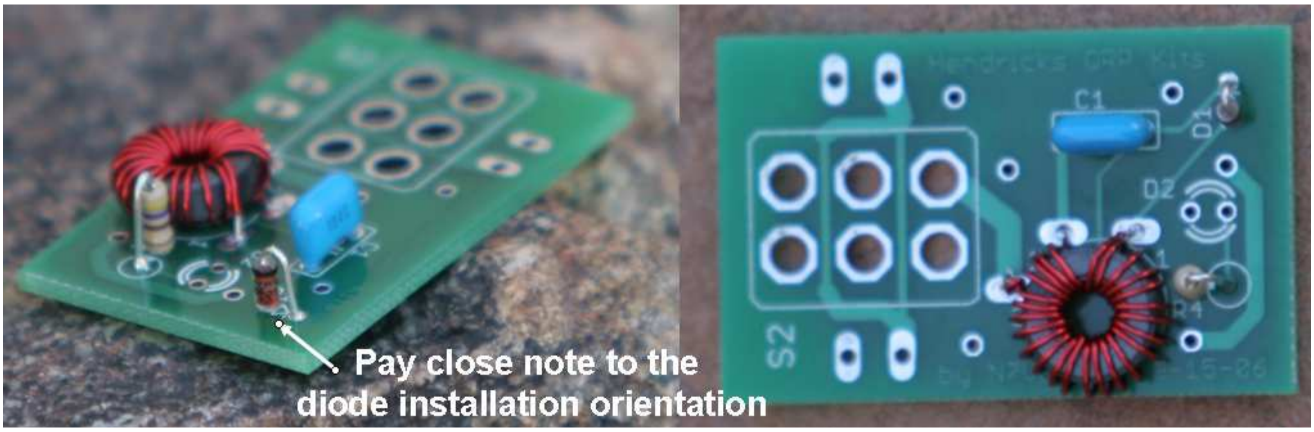

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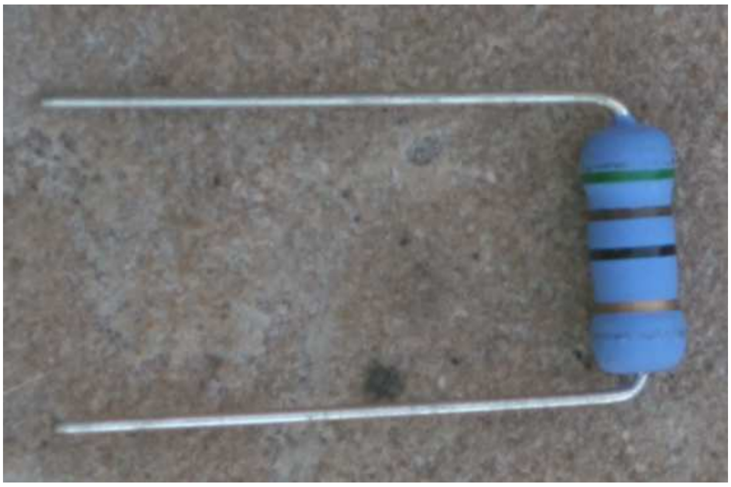

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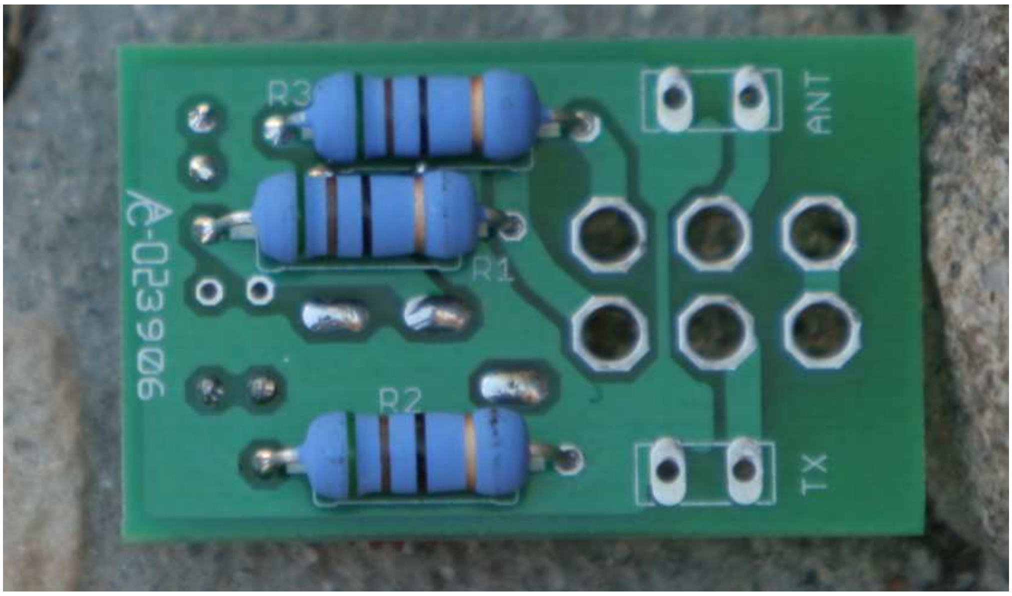

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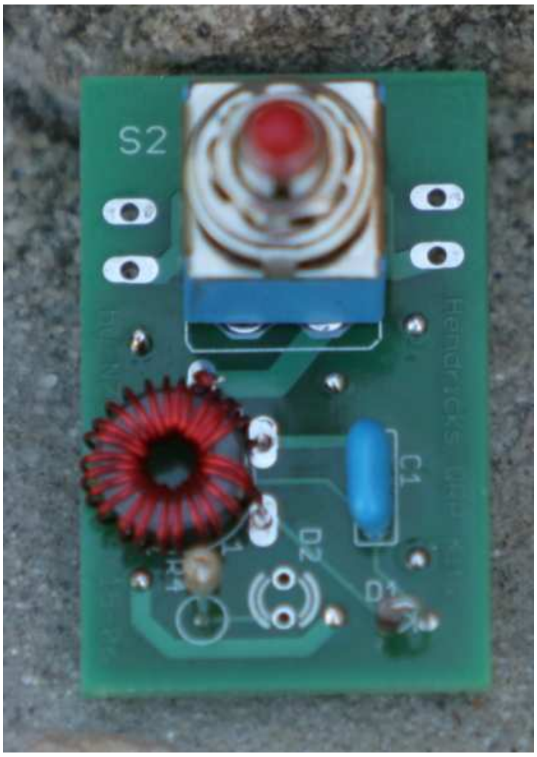

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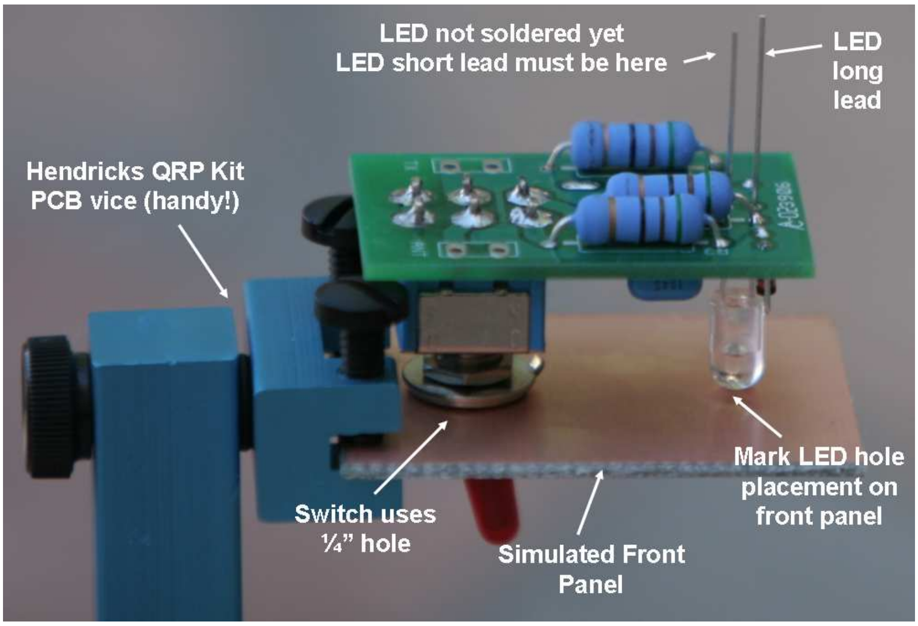

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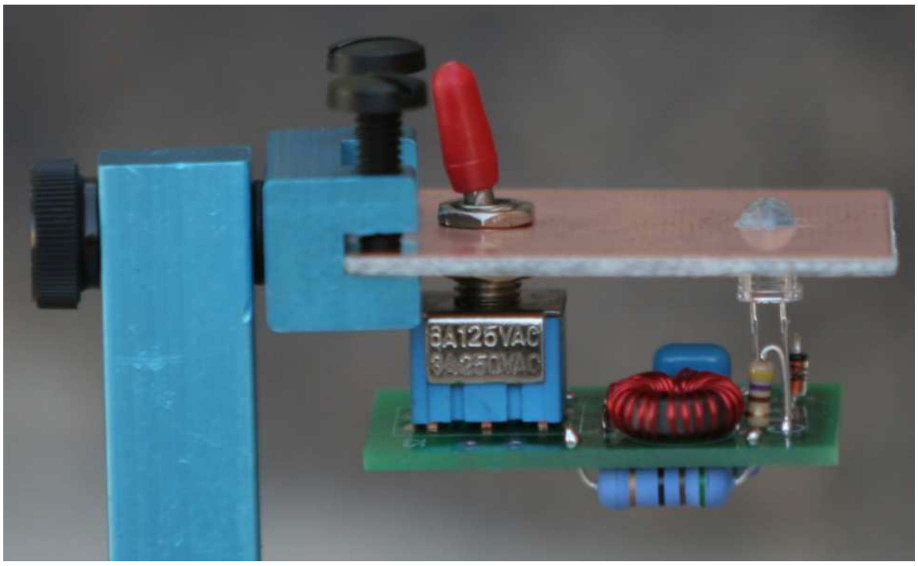

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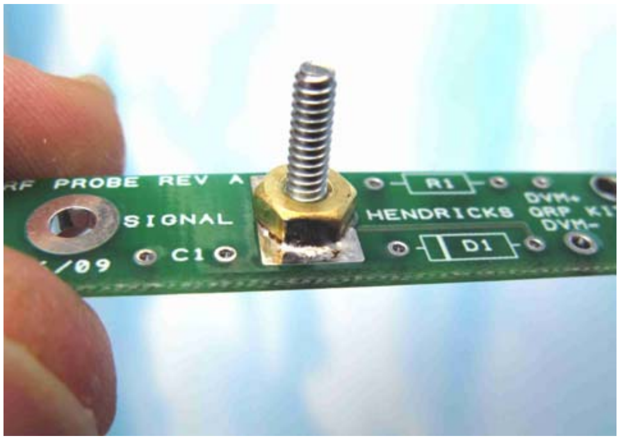
Hendricks RF Probe assembly

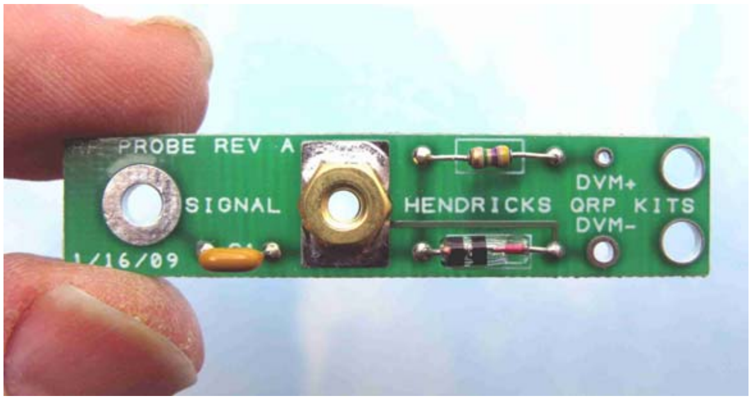
First off, check to see if the parts match the parts list…

1 – 1/2” x 3” CPVC tube
2 – 5/8” O.D. vinyl caps
1 – 3/32” dia x 2.5” brass rod
1 – 4-40 x 7/16” pan head screw
1 – 4-40 x 1/4” pan head screw
2 - #4 internal tooth lock washer
1 – 4-40 nut, steel
1 – 4-40 nut, brass
1 – 3/32 x 2” tyrap
2 - #4, 14-16ga ring terminal
1 – PCB
1 – D1 - 1N34A diode
1 – R1 - 4.7M 1/8w resistor (YEL, VIO, GRN, GLD) **See note**
1 – C1 - .01 disk ceramic capacitor (103)
3’ – RG-174 coax
2 – banana plugs, 1 red, 1 black
2” – 3/16” dia. shrink tubing
1 – alligator clip and 9” lead
1 - copper foil tape, 2.25” x 2”
1 – self adhesive label

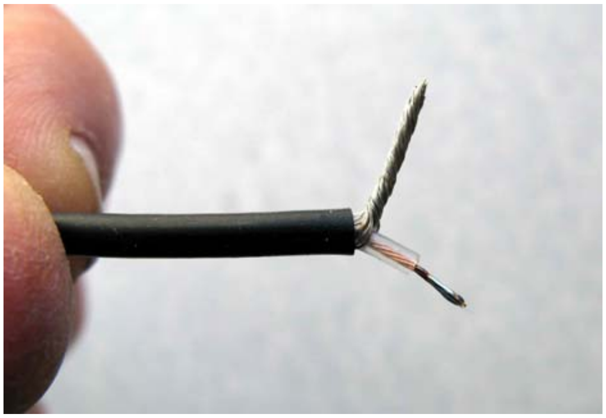
Note: If your multi meter has a different input resistance than the standard 10 to 11 Meg Ohm, for example, 22 Meg Ohms, You can figure out the scaling resistor (Rs) value by multiplying the multi-meter's input resistance Rm by 0.414. For example: Rs = 22.00 x 0.414 = 9.018 Meg Ohm; instead of 4.7 Meg Ohms.



Solder the 4-40 “brass” nut to the top of the pcb. Use the 7/16” long pan head screw threaded from the bottom to position and hold the nut in place, while you are soldering it. Then, remove the screw.

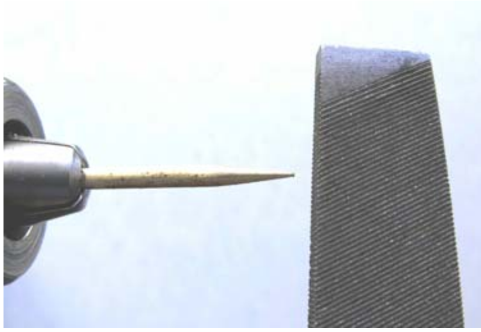


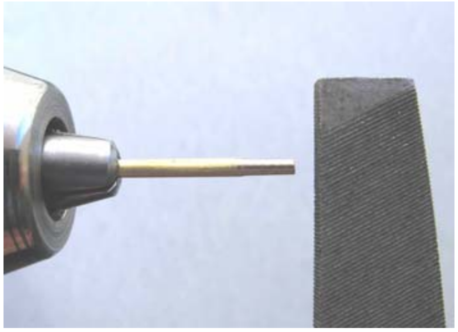
Next, we’ll assemble the small pcb. Solder C1, R1, and D1 to the top of the pcb. Note and match the band on the 1N34A diode to the band on the silk screened pcb.

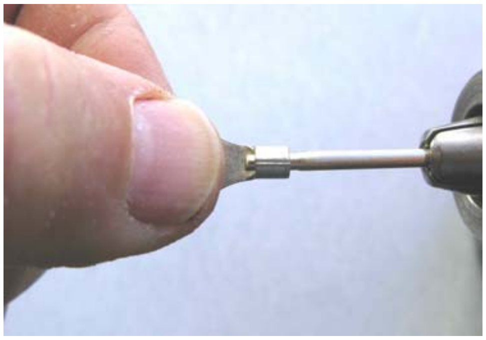


Strip and prepare as shown, 3/8” of one end of the RG-174 coax cable.

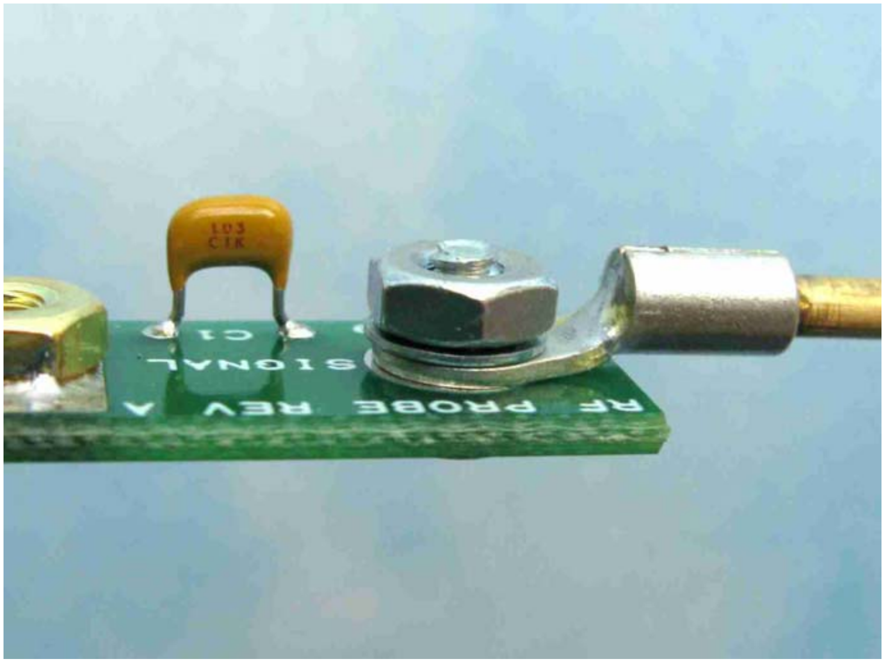
Solder the center conductor to the pad marked DVM +, and the shield to the pad marked DVM -. Secure the coax to the pcb using the cable tie supplied. Rout the tie as shown so the clinch is on the top of the pcb, not underneath.



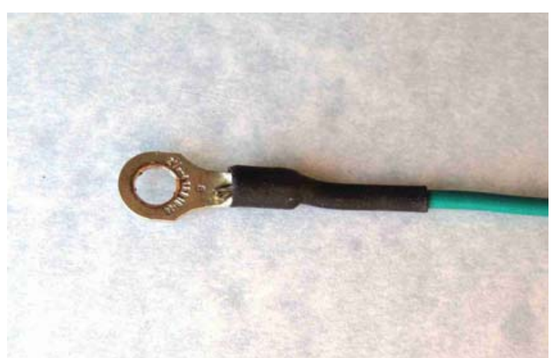




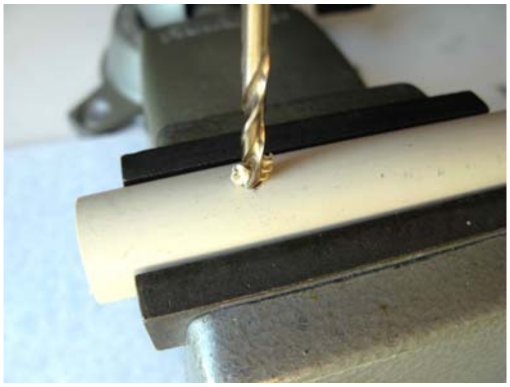
File a contact point on one end of the 3/32” brass rod as shown. File down the other end of the brass rod to accept one of the #4 ring terminals, and solder it in place. An electric drill makes it easy, but you can do it by hand as well



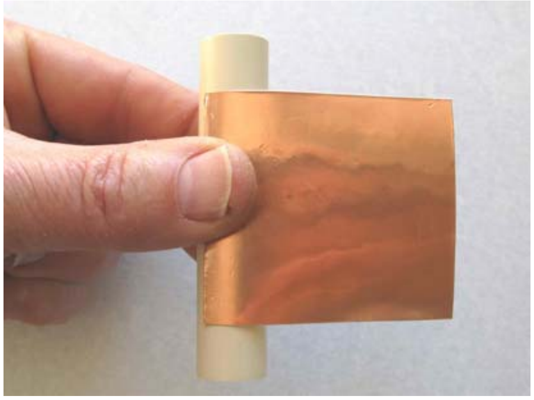
Secure the contact point and ring terminal assembly to the signal pad of the pcb using the 4-40 x 1/4" pan head screw, lock washer, and steel nut in the order shown. The screw head should be on the bottom of the pcb, then the pcb, ring terminal, lock washer, and finally the nut.

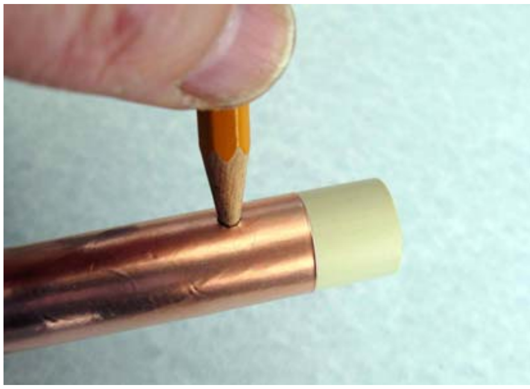


Slide the plastic boot back from the alligator clip and solder the lead to the clip. Sometimes these are crimped only, and can lose conductivity. Replace the boot. Place 1" of the 3/16" dia. heat shrink tubing over the loose end of the clip lead. Solder the lead assembly to one of the #4 ring terminals, and shrink the tubing to the transition from the ring terminal to the lead. Color may vary from picture. Set it aside for later assembly.

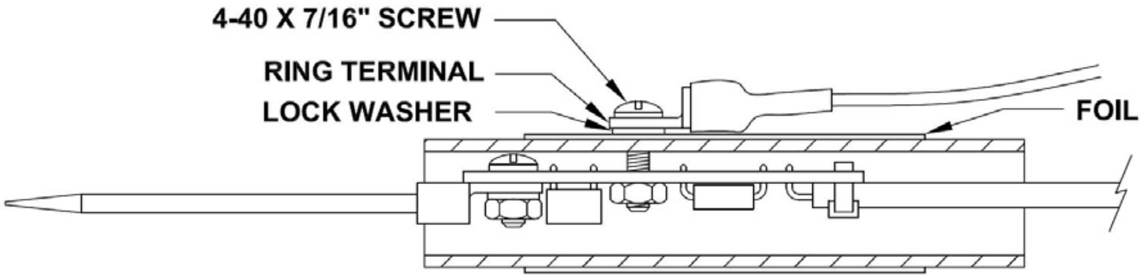


Mark and drill a 1/8” dia. hole in the side of the 3” long CPVC tube, 1-1/8” from the end.

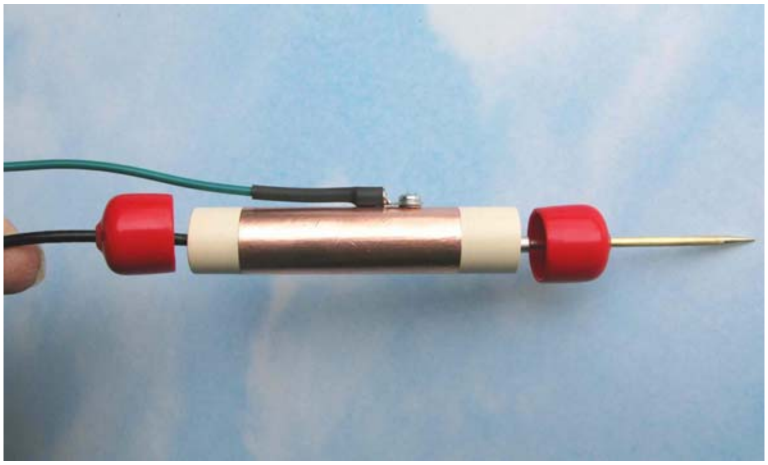




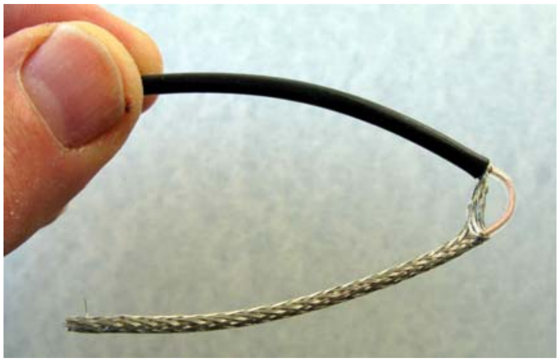
Install the copper foil tape. First, peel off the protective backing, and wrap the foil around the CPVC tube as shown. The 2 1/4” long side goes around the tube, and 2” long side, the length of the tube. Wrap it as shown so it is in the center of the tube, approx. 1/2” from the end. Now, poke a hole in the copper with a pencil, for the screw to pass through the 1/8” dia. hole.

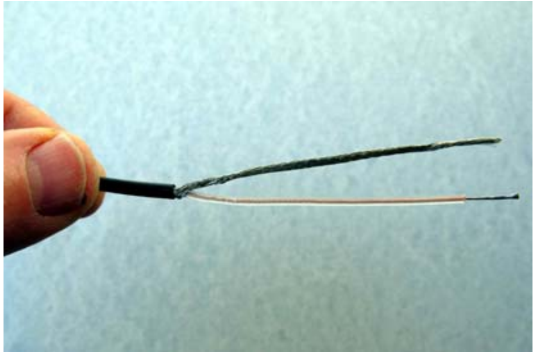


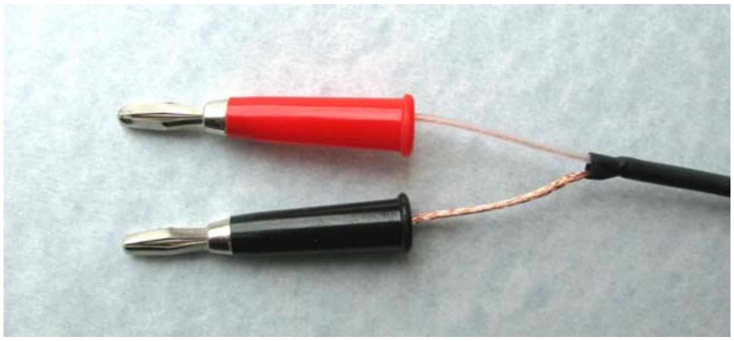
Slide the pcb in to the tube, with the bottom of the pcb facing the side hole in the CPVC tube. Attach the alligator ground clip assembly to the outside of the CPVC tube, as shown, using the 7/16” long pan head screw, and lock washer. The correct order should be, 4-40 screw, ring terminal, lock washer, and copper covered CPVC tube, with the screw passing through the 1/8” hole into the bottom of the pcb, and eventually to the brass nut. Secure, but do not over tighten.



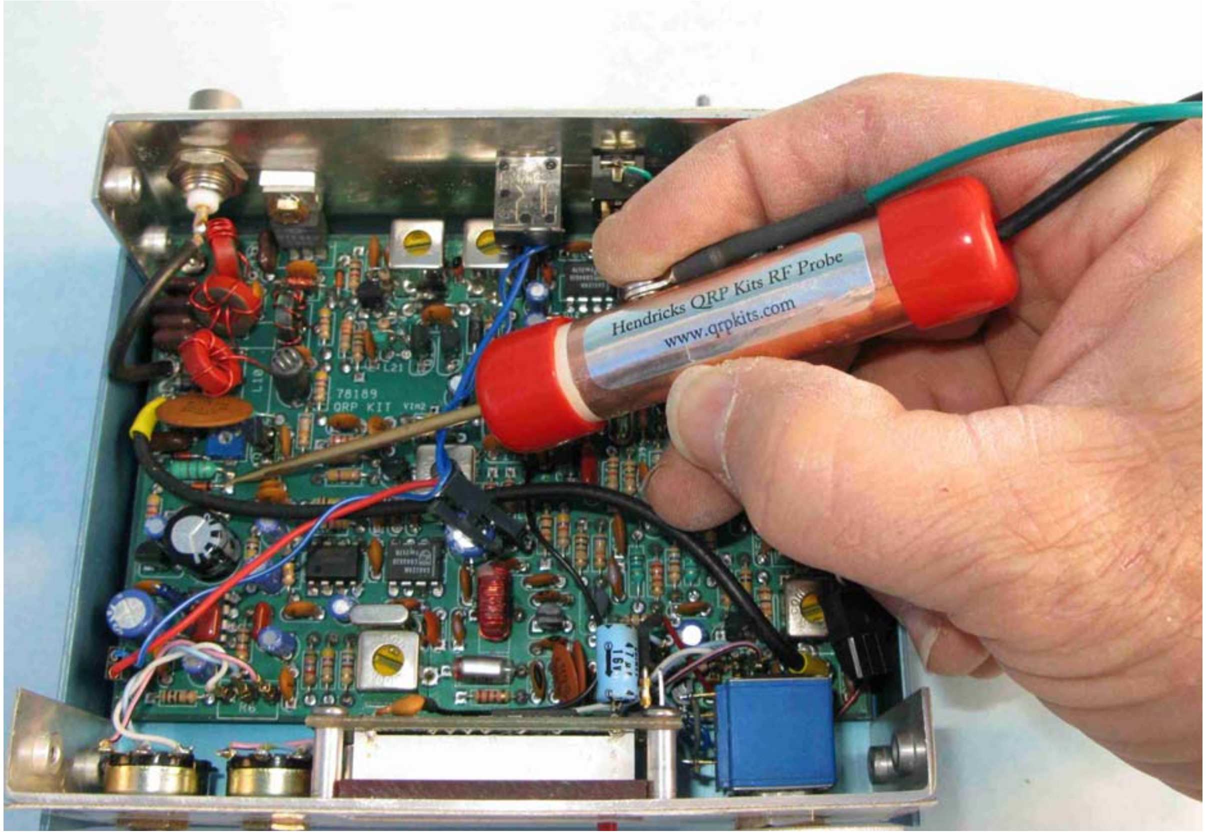
Poke a hole in the center of both vinyl caps, with your probe tip. Slide one of the vinyl caps over the probe end and the other cap over the loose end of the RG-174 lead, and slide onto the CPVC body.





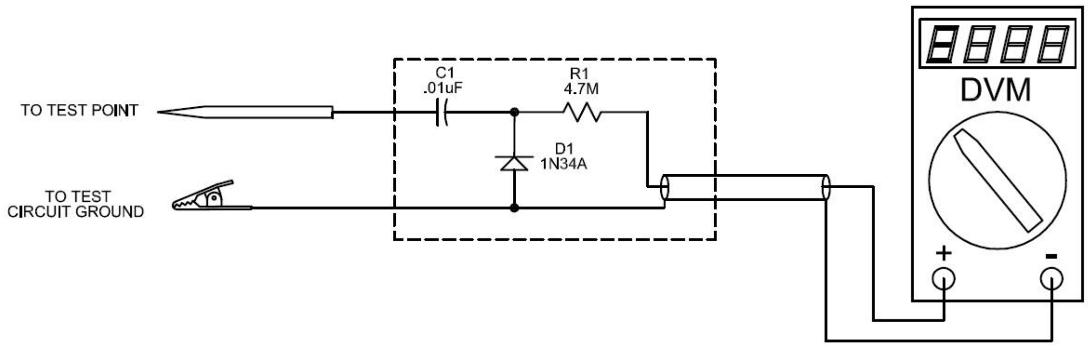


Finally, strip 2 1/2” and prepare as shown the end of the RG-174. Pass the center conductor through the side of the braided shield, as shown. Slide the remaining piece of shrink tubing over the end before attaching the banana plugs. Attach the center conductor of the coax to the RED plug and the shield to the BLACK plug, and shrink the tubing at the transition.



Stick on the Hendricks label, and you are finished.

Look in the files section for **Dar's (Darwin Piatt) – W9HZC** application and usage tips for the R.F. Probe.

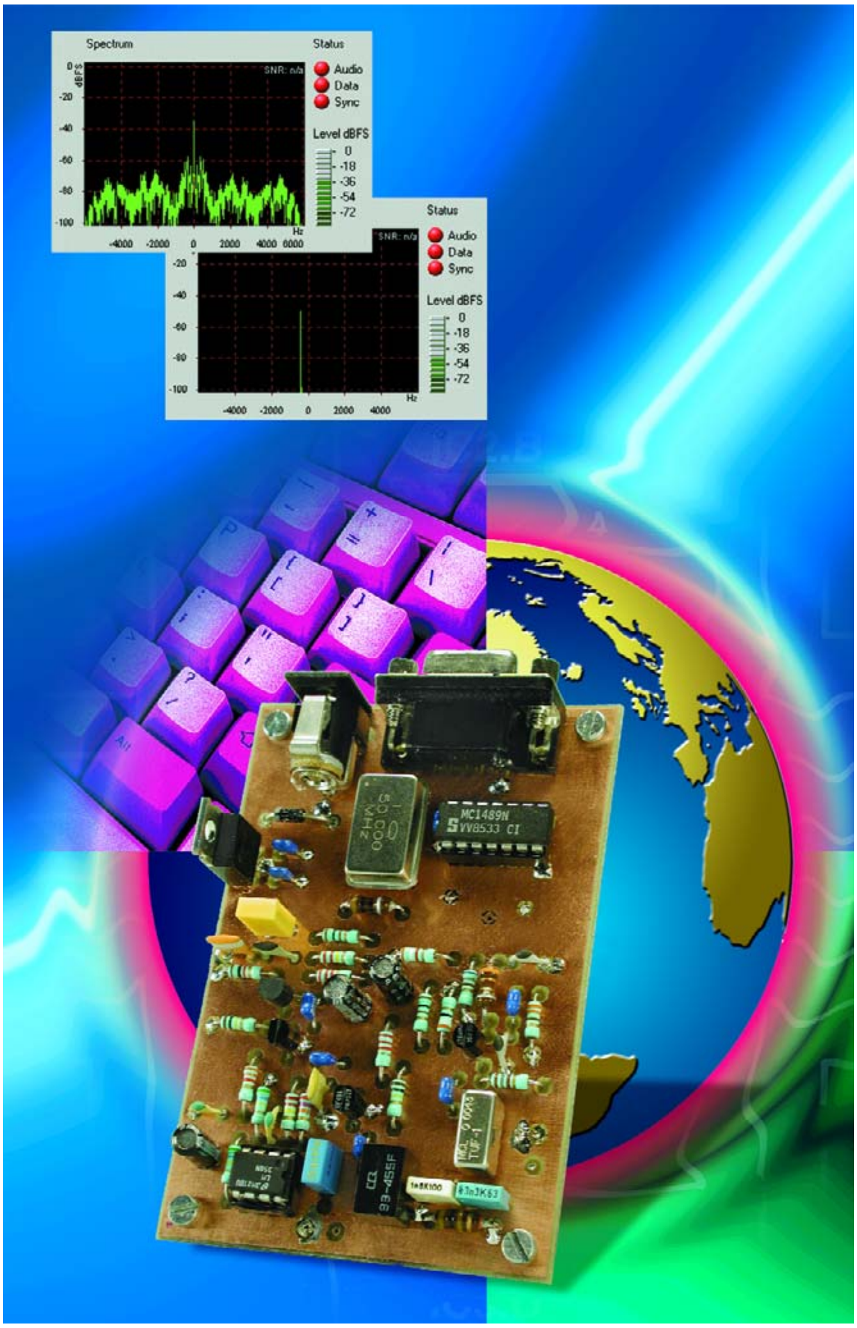


Build Your Own DRM Receiver

A digital radio for 500 kHz to 22 MHz

Design by B. Kainka

One again Elektor Electronics makes its competitors take a very distant back seat by publishing the world's first homebuilt DRM receiver for digital (MP4-quality) broadcasts in the medium and shortwave bands. The receiver is of a surprisingly simple design and supplies a 12-kHz output signal for easy connection to your PC's soundcard which handles the demodulation and MPEG decoding. The receiver is also tuned by the PC via an RS232 link.



On 15 December 2003, DRM (Digital Radio Mondial) entered a new phase on the shortwave and medium-wave bands. The encoding was changed to MP4 in order to improve the quality of the received audio signals even further. The unique receiver described in this article was developed for all readers interested in listening to DRM broadcasts at a modest investment.

One of the targets set for the design was good receiver performance without any adjustment points. No special inductors or tuning capacitors are used in this project, just off-the-shelf fixed inductors. This, we hope, encourages those readers with more experience in digital electronics than RF design and construction. There's no adjustment to worry about and no need for special test equipment. A very simple software-driven alignment is sufficient to illuminate tolerances in the oscillator frequencies used in the circuit.

The basic operation of DRM and in particular its signal encoding and transmission method was described in *Elektor Electronics* December 2002 [1]. Exactly one year later, in the December 2003 issue [2] we ran an article describing how DRM signals could be picked up and turned into audio using an experimental receiver based on our DDS RF Signal Generator and a PC or notebook. The present DRM receiver also contains a DDS (direct digital synthesis) chip. The two articles mentioned above provide a good technical background to the workings of DRM and were published at a time when none of our competitors was able to come up with technical specifications on DRM let alone an experimental yet reproducible receiver. The publication of this article is sure to increase the distance.

A DRM interface

It is perfectly possible to view the receiver as a DRM interface for the PC. As illustrated in **Figure 1a**, the DRM receiver has two links to the PC. By way of an RS232 connection, it gets digital control information for tuning the DDS to the desired DRM broadcast station.

As opposed to a normal radio or general coverage receiver the DRM receiver does not supply an audio signal you can make audible using analogue means like headphones, a loudspeaker or an audio amplifier. Internally, the DRM receiver mixes the signal received from the DRM station down to an IF (intermediate frequency) of 12 kHz. Its output therefore supplies a mix of modulated carriers that together convey the audio signal in the form of a digital datastream. This DRM spectrum, a mix of various frequencies covering a bandwidth of 10 kHz, is connected to the Line input of the PC soundcard. Alternatively the Microphone input may be used if the signal is rather weak. The DRM signal is digitised by the soundcard, while a special DRM receiver program looks after the demodulating of the DRM signal as well as the decoding of the MP4 datastream. Again, all demodulation and decoding is done in software. The resulting hi-fi stereo audio signal is then available at the output of the soundcard for reproducing by a (PC) loudspeaker or headphones.

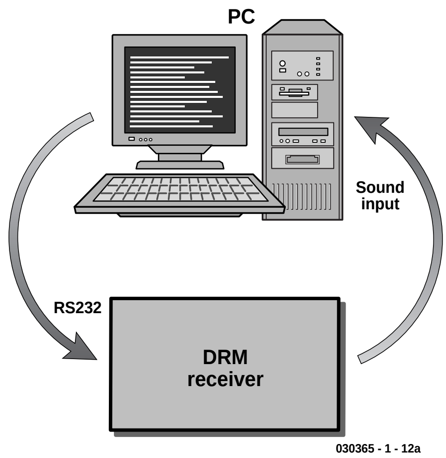


Figure 1a. The DRM receiver has two connections to the PC: a serial link for the receiver tuning and a connection feeding an MPEG datastream to the Line or Microphone input on the soundcard. All decoding and demodulation is done in software.

Double-conversion

As you can see from the block diagram (**Figure 1b**), the signal received from the DRM station is mixed two times — first, a variable oscillator frequency is used to mix it down to a fixed intermediate frequency (IF) if 455 kHz. This provides the station tuning on the receiver. The second heterodyning operation is against a fixed 467 kHz signal in order to mix the 455-kHz signal down to 12 kHz. Using receiver terminology, the DRM receiver is a 'double-conversion' or 'super-heterodyne' type. The first injection signal is obtained from a synthe-

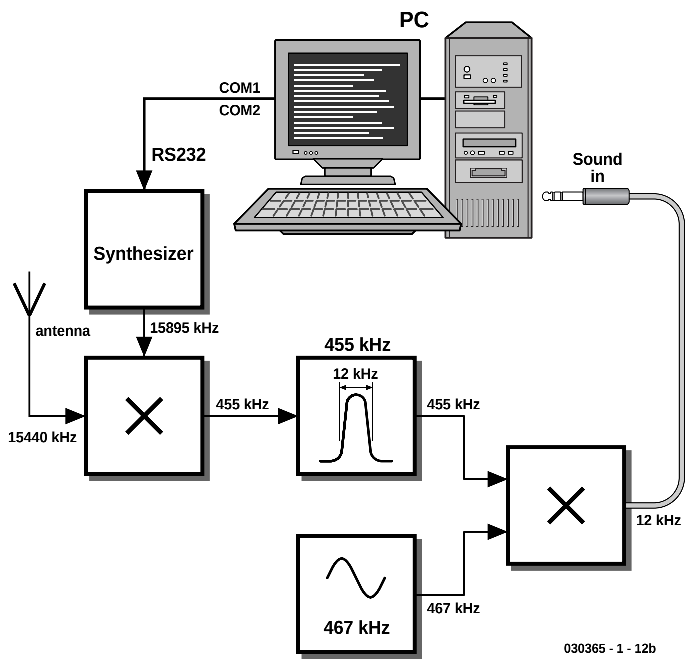


Figure 1b. The block diagram of the DRM receiver reveals a double-conversion ('super-heterodyne') design with intermediate frequencies at 455 kHz and 12 kHz.

sised oscillator supplying an output frequency that's programmable by means of control data generated on the PC and sent to the receiver over the RS232 link. The second injection signal at 467 kHz originates from a ceramic resonator.

Practical circuit

The block diagram is easily found back in the circuit diagram shown in **Figure 2**. The DDS oscillator based around IC2 supplies an output signal to the first mixer (MIX1) via a buffer stage, T1. In case you've never seen such a beast, MIX1 is a wideband double-balanced diode ring mixer. The IF signal at 455 kHz is taken through a steep ceramic filter (Fl1) with 12-kHz bandwidth. An IF amplifier stage around T2 raises the level by about 20 dB before the signal is applied to the second mixer comprising (passive) FET T4, a type BF245. The second injection oscillator is frequency-stabilised by a CSB470 ceramic resonator (X1) whose nominal output frequency is pulled down by 3 kHz to arrive at 467 kHz. The 12-kHz IF signal at the drain of T4 goes through a

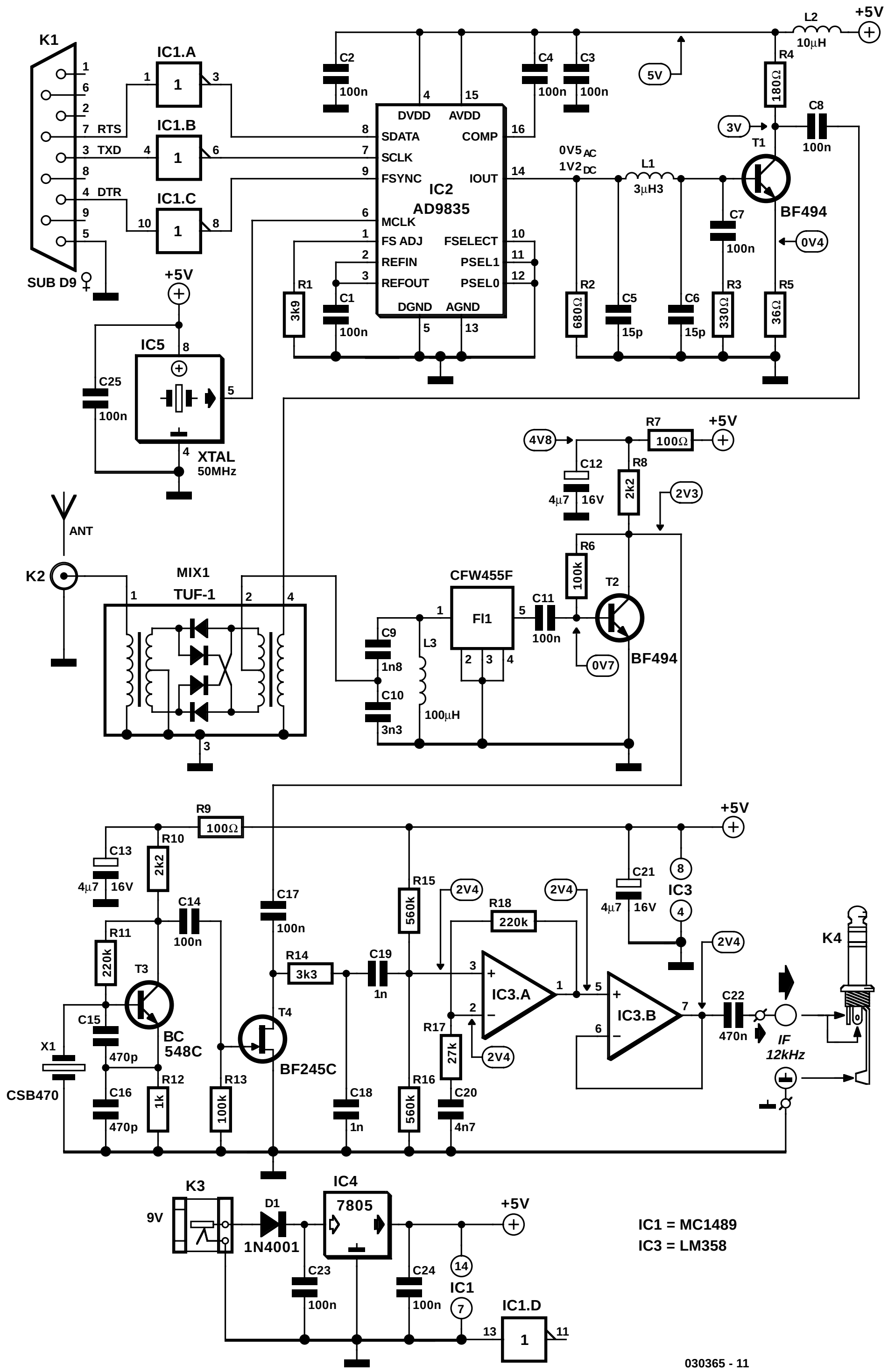


Figure 2. The practical circuit of the DRM receiver is marked by PC-driven tuning of a DDS oscillator and two large-signal resistant mixers.

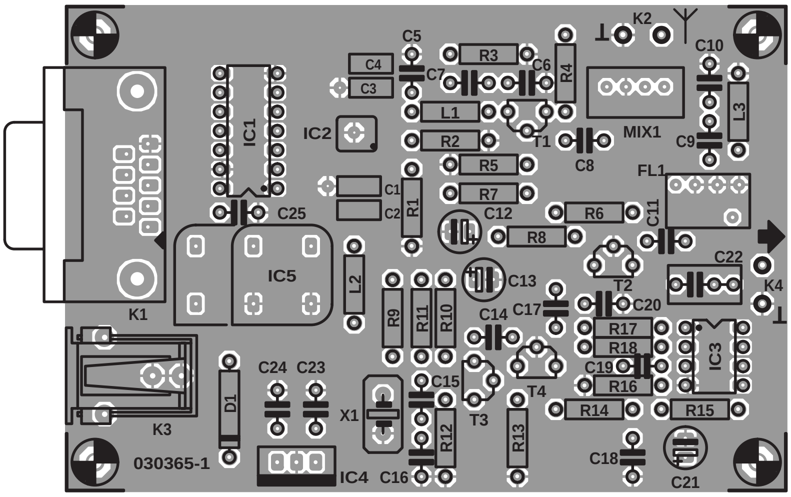


Figure 3. The PCB is double-sided and through-plated. All parts in the RF sections have to be soldered with the shortest possible lead lengths.

COMPONENTS LIST

Resistors:
R1 = 3kΩ9
R2 = 680Ω
R3 = 330Ω
R4 = 180Ω
R5 = 39ΩΩ
R6,R13 = 100kΩ
R7,R9 = 100Ω
R8,R10 = 2kΩ2
R11 = 220kΩ
R12 = 1kΩ
R14 = 3kΩ3
R15,R16 = 560kΩ
R17 = 27kΩ
R18 = 220kΩ

Capacitors:
C1-C4 = 100nF, SMD, case shape 1208
C5,C6 = 15pF
C7,C8,C11,C14,C17,C23,C24,C25 = 100nF, lead pitch 5mm
C9 = 1nF8, lead pitch 5mm
C10 = 3nF3, lead pitch 5mm
C12,C13,C21 = 4µF7 16V radial
C15,C16 = 470pF
C18,C19 = 1nF, lead pitch 5mm
C20 = 4nF7, lead pitch 5mm
C22 = 470nF

Inductors
L1 = 3µH3
L2 = 10µH
L3 = 100µH

Semiconductors:
D1 = 1N4001
T1,T2 = BF494
T3 = BC548C, BC549C or BC550C
T4 = BF245C
IC1 = MC1489N
IC2 = AD9835 BRU (Analog Devices)
IC3 = LM358N
IC4 = 7805
IC5 = 50MHz oscillator module in 8-way or 14-way DIP case

Miscellaneous:
K1 = 9-way sub-D socket (female), angled pins, PCB mount
K2 = 2 solder pins
K3 = mains adapter socket
K4 = cable with 3.5-mm mono or stereo jack plug
MIX1 = TUF-1 (Mini Circuits)
FL1 = CFW455F (455kHz ceramic filter, bandwidth 12kHz) (Murata)
X1 = CSB470 (470kHz ceramic resonator) (Murata)
RS232 cable with 1:1 pin connections, plug and socket, **no** zero-modem or crossed wire cable.
PCB, order code **030365-1***
Disk, PC software DRM.exe, order code **030365-11*** or **Free Download**

* see Readers Services page or visit www,elektor-electronics.co.uk

Suggested component / kit suppliers:

- Geist Electronic (www.geist-electronic.de)
- Segor electronics (www.segor.de).
- AK Modul Bus (www.ak-modul-bus.de)

simple bandpass filter before it is buffered and amplified for another 20 dB by two opamps, IC3.A and IC3.B. The output of the second opamp supplies the MPEG datastream to the PC soundcard input via coupling capacitor C22.

The nitty-gritty of DRM reception is not stability or even spectral purity but **extremely low phase noise of the injection oscillator**. In this respect the DDS VFO gets full marks because it fully meets this requirement, hence our DIY DRM receiver is an excellent performer. Another important design consideration, large-signal response, is fully covered by the passive double-balanced mixer used. The results obtained from our prototype were impressive, to say the least: with a simple wire antenna connected to the receiver input, the DRM software achieves 30 dB quieting, a value only matched by expensive receivers.

Because a couple of characteristics that are crucial in the context of AM reception are less important with DRM, the circuit is able to achieve such excellent results despite the heavily simplified and alignment-free realisation.

The joint dynamic range of the DRM software and the PC soundcard is sufficient to cope with signal variations of up to 30 dB, which are not uncommon on SW and MW. This conveniently saves on an ALC (automatic loudness control) circuit. High receiver sensitivity is not an issue for DRM. Very weak DRM signals (say, below 10 μV) do not improve by increasing the receiver gain because the actual signal to noise ratio is insufficient at a large bandwidth like 10 kHz. A number of practical tests proved that the receiver can make do without a tuned front-end. For one, the image frequencies at a distance of 910 kHz (2 x 455 kHz) will nearly always fall outside the neighbouring broadcast bands. On the other hand, the DRM software is remarkably tolerant of interference thrown at it.

Of course, the above considerations should not keep you from using a preselector and a matching antenna if you have a fine combination available. If not, rest assured that a 3-10 m long free-hanging wire is sufficient for direct connection to the mixer RF input.

Details

The antenna input directly on the double-balanced TUF-1 mixer has an impedance of 50 Ω. The mixer does the frequency conversion to 455 kHz at a low impedance. The TUF-1 is designed for a frequency range of 2-600 MHz. However, it may operate below 2 MHz with some reduction in the input impedance and

the occurrence of a strong inductive component. In practice, however, the receiver was found to work satisfactorily even down to 500 kHz in the MW range.

The output of the ring mixer is connected to a wideband matching network for 455 kHz. The impedance is stepped up using a resonant circuit with a 1:10 ratio capacitive tap. The result is an impedance of about 1 kΩ to suit the CFW455F ceramic filter. High accuracy is not an issue here because the actual antenna impedance will typically be higher than 50 Ω. The resonant circuit employs a fixed 100-μH inductor with a low Q factor (<10), ensuring a bandwidth greater than about 50 kHz yet avoiding component tolerance issues. Consequently, no alignment is required on the inductor while the step-up matching circuit still adds to the remote signal rejection of the IF filter.

The CWF455F has a bandwidth of 10 kHz, with 10 kHz being occupied by DRM and the remaining 2 kHz, well, harmless. Actually, a little more bandwidth is important to have as it provides a way of compensating frequency deviations of the second injection oscillator. For example, if the oscillator runs at 467.5 kHz instead of 467.0 kHz, the first IF is automatically shifted up to 455.5 kHz, which may be countered by the software retuning the DDS 500 Hz ‘up’. After all, a nominal frequency of 12 kHz must be maintained at the output of the receiver. The slightly shifted IF will easily fit in the bandpass of the IF filter, allowing us to omit an expensive second oscillator and design one around a cheap ceramic resonator type CSB470. Due to the large capacitance presented by the oscillator (C15 and C16), the resonator is pulled down 3 kHz with a tolerance of about 1 kHz.

The IF signal is raised by about 20 dB by a single transistor stage (T2). Overdriving is unlikely to occur because the signal levels are relatively small due to the slight attenuation by the IF filter and the absence of prestage or mixer gain.

JFET T4 operates as a passive mixer, that is, a switch for RF signals, being opened and closed by the 467-kHz local oscillator signal. Besides utter simplicity, the main advantage of a passive FET mixer is its large dynamic range — signal levels up to 100 mV are handled without problems.

DDS tuning

The DDS VFO based on an AD9835 from Analog Devices is controlled almost directly from the PC’s serial port. An MC1489 RS232 receiver chip (IC1) takes care of the swing conversion. Although the DDS clock signal of 50 MHz would allow a highest receiver fre-

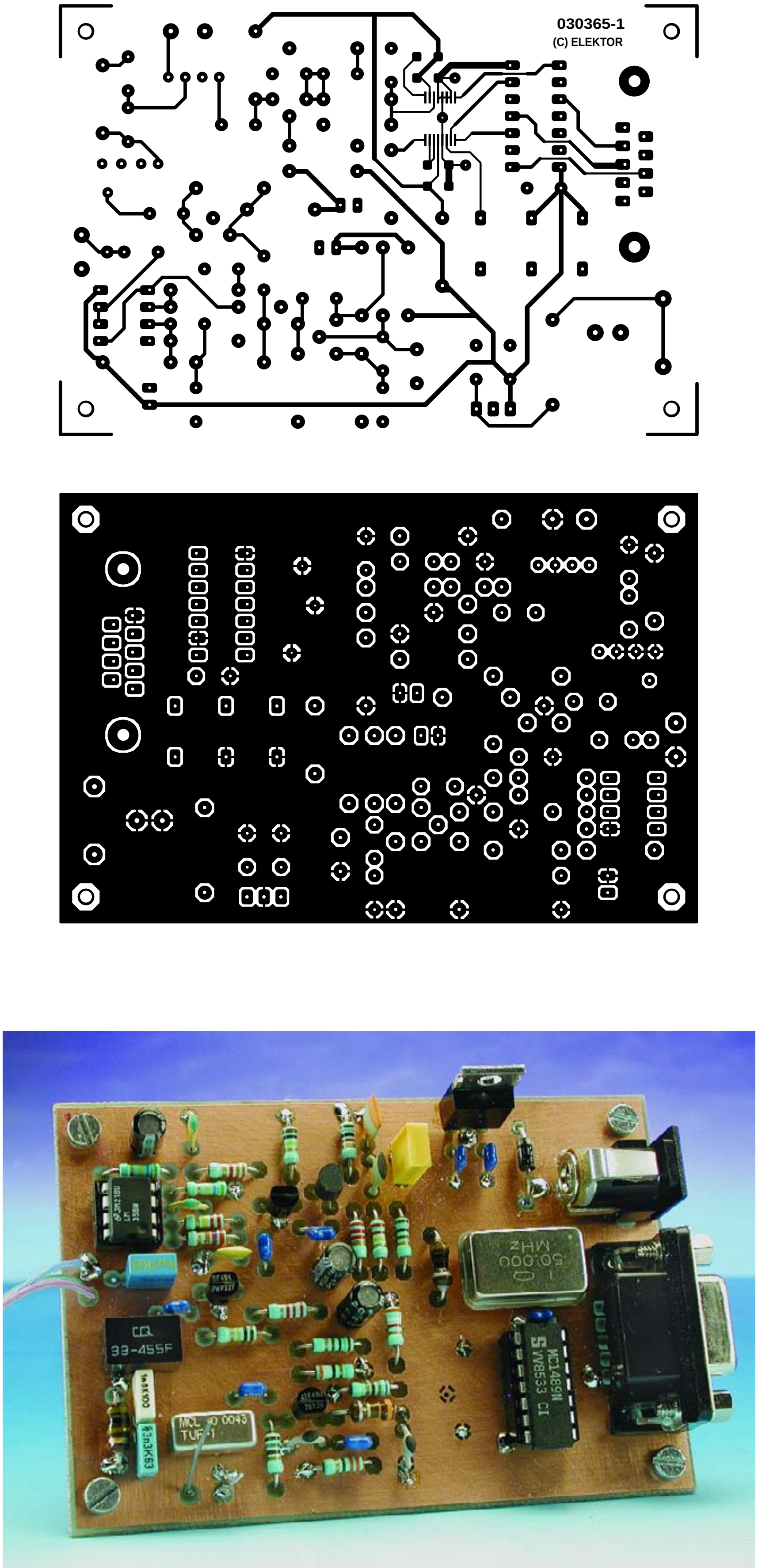


Figure 4. Component mounting plan of the board tested and approved by the Elektor design laboratory. The large copper plane allows short ground connections.

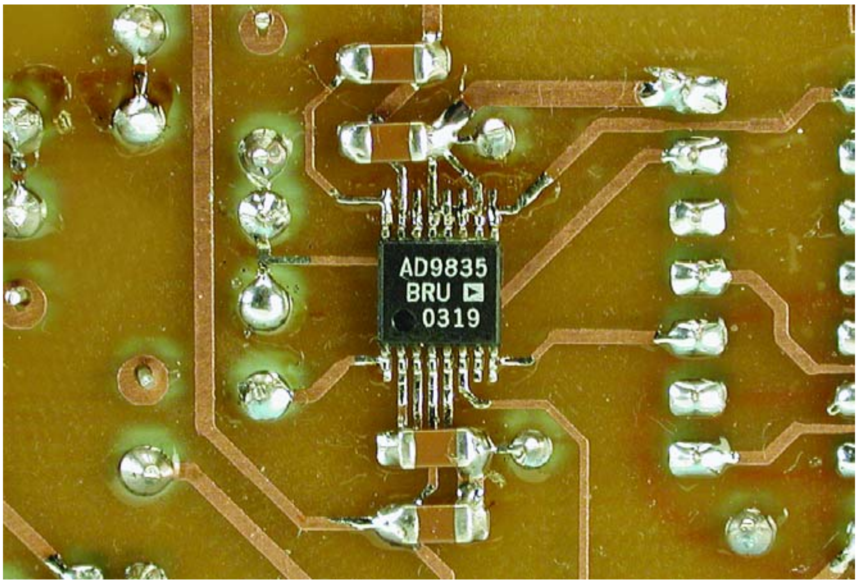


Figure 5. The DDS IC (only available in an SMD case) is soldered to the underside of the board, together with four SMD capacitors.

quency of 25 MHz, the output signals near this frequency become too weak and 24 MHz should be regarded as the absolute limit. A simple low-pass filter (C5, L1, C6) with a roll-off at about 24 MHz provides sufficient rejection of harmonics. Likewise, an additional amplifier, T1, ensures sufficient LO drive for the mixer.

Analog Devices offers a wide range of DDS integrated circuits including a few with a higher clock frequency. The AD9835 was chosen for its relatively low cost and easy availability (Segor Electronics, Geist Electronics, Barend Hendriksen). The low intermediate frequency of 455 kHz causes a VFO frequency that's only a little above the received signal. The upper limit of the VFO frequency range is not sharply defined — the VFO output level will simply drop gradually above 20 MHz or so. As an aside, this allowed us to receive the Deutsche Welle DRM broadcast from Trincomalee, Sri Lanka, without too much of an effort.

The receiver is tuned by a program called DRM.exe, which makes provision for the receiver calibration. The inset 'Step-by-Step' tells you how to start using the receiver. When DRM.exe is first started, it needs to be told which COM port you want to use. The program default is COM1 which may be changed into COM2, for example. By clicking on 'Save Setup' the COM port selection is saved in a file called 'init.txt', along with a few other salient parameters for easy retrieval the next time the program is used. As soon as the serial connection is successfully established, the slider (at the top in **Figure 6**) may be used to tune the receiver with 1-kHz resolution. The arrows at the edges cause 1-kHz steps, a click in the areas beside the slider, a step of 10 kHz.

Calibration

Frequency calibration is required because the two local oscillators in the receiver are subject to a certain tolerance for which no hardware adjustments are available. First, the software needs to know the exact frequency of the 467-kHz oscillator. Adjust the receiver frequency to 0.00 (slider to leftmost position) and start the DRM software. *(Note: in the following description is it assumed that the program 'DRM Software Radio' from Fraunhofer IIS is used — however, it is also possible to employ 'Dream' (see 'Decoder Software' inset).* No antenna should be connected at this point. The spectrum (**Figure 7**) will show a straight line caused by the first oscillator being tuned to the intermediate frequency. *(Note: if the receiver were switched on after*

Step-by-step

The following sequence is suggested when connecting the receiver to a PC.

1. Connect the 1:1 RS232 cable to the PC and the receiver.
2. Connect the receiver output to the Line input of your soundcard by means of a screened audio cable.
3. Switch on the receiver,
4. Launch the DRM software on the PC; select soundcard as target and source.
5. Double-click on the loudspeaker symbol in the right-hand bottom corner of the Windows desktop (or via Programs – Accessories – Entertainment – Volume Control) to open the volume control window (the one with the slide controls).
6. Select Properties, then Options and check the box Adjust volume for: **Recording**.
7. Check the box for the soundcard input you want to use (Line or Microphone) and click OK.
8. In the window that pops up, adjust the volume of the desired input.
9. Return to Options – Properties and now select **Playback**. Disable all inputs (remove the check mark) except for the one you're using for the receiver (normally **Wave**). Use the two slide controls at the left-hand side to control the volume on the PC loudspeakers.
10. Launch DRM.exe to tune the receiver to a DRM station.

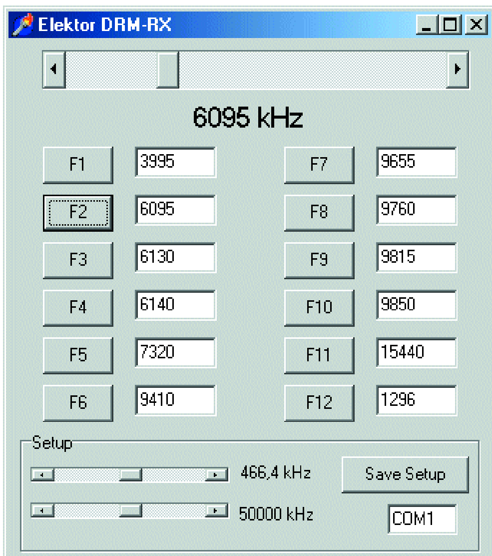


Figure 6. Windows program DRM.exe for the receiver tuning in action.

launching the software, the line does not become visible after you've moved the slider a little. If the line still does not appear, the receiver's output signal may be too small for the Line input — change to the microphone input and try again. Receiver noise should be just visible in the lower part of the screen. Possibly, the line falls outside the screen area — adjust the slider until the line appears). Next, the upper slider in the Setup Range has to be adjusted for the line to appear exactly in the centre of the spectrum. If that is achieved, the

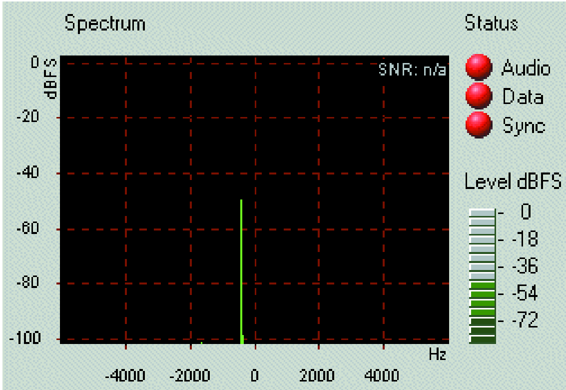


Figure 7. Illustrating IF calibration, here using the program DRM Software Radio (v. 2.034).

Listing 1

VB code snippets

```
Const XTAL = 40000
Const IF1 = 454.3

Private Sub output(Data)
  TXD 0
  Delay 0.1
  DTR 1              ' CE
  Delay 0.1
  BitValue = &H8000&
  For n = 0 To 15
  If (Data And BitValue) >
   0 Then RTS 0 Else RTS 1
    Delay 0.1
    TXD 1            ' clock
    Delay 0.1
    TXD 0
    Delay 0.1
    Delay 0.1
    BitValue = BitValue \ 2
  Next n
  Delay 0.1
  DTR 0
  Delay 0.1
End Sub

Private Sub LO(freq)
  HScroll1.Value = freq
  Label1.Caption =
      Str$(freq) + " kHz"
  Dim frg As Long
  Dim freqLo As Long
  Dim freqHi As Long
  Dim Daten As Long
  freq=freq+IF1 'add IF1
  frg=Int(freq/XTAL*
         4294967296#)
  freqHi=frg\&H10000
  freqLo=frg-freqHi*&H10000
  freqLoL=freqLo And &HFF
  freqLoH freqLo\&H100
  freqHiL=freqHi And &HFF
  freqHiH=freqHi \ &H100
  output &HF800& 'Reset
  '4 Bytes to FREQ0
  output(&H3000& + freqLoL)
  output(&H2100& + freqLoH)
  output(&H3200& + freqHiL)
  output(&H2300& + freqHiH)
  output &H8000& 'Sync
  output &HC000& 'Reset end
End Sub
```

receiver supplies an output signal of exactly 12 kHz. On our prototype, the setting was found to correspond to a frequency of 466.4 kHz from which we can conclude that the second oscillator had an error of 600 Hz. This error, then, is compensated by the software offsetting the DDS oscillator by the same amount. The adjustment range of the calibration is ±2 kHz.

The second step is to eliminate the error in the DDS clock oscillator frequency. The 50.000-MHz quartz crystal oscillator has a basic tolerance of ±100 ppm or 100 Hz per MHz, so that a final error of up to 5kHz may occur at 50 MHz. Consequently, the error would be 1 kHz for a receive frequency of 10 MHz. The calibration begins by connecting the antenna to the receiver input and tuning to a strong AM station in the shortwave range (tune using the top slider in DRM.exe). The vast majority of SW broadcast stations can be used as frequency standards, their station frequencies complying with high stability standards and a 5-kHz raster. **Figure 8** shows the spectrum of an AM transmitter at 6805 kHz. The lower slider has to be adjusted for the carrier to occur exactly in the centre.

Theoretically, a this point you would have to repeat the first calibration step, then the second and so on. In practice, that is not necessary because the small error in the clock oscillator frequency amounts to no more than 1% in the IF range. With an error of 1 kHz at 50 MHz established, the error at 455 kHz is an insignificant 10 Hz. The DRM software we propose to use requires an absolute accuracy of 'just' ±500 Hz.

When you are done calibrating the oscillators, do not forget to save the setup data to make them quickly available again the next time the receiver is switched on. By the way, more data is saved, including the current station frequency. Station buttons may be linked to your pre-

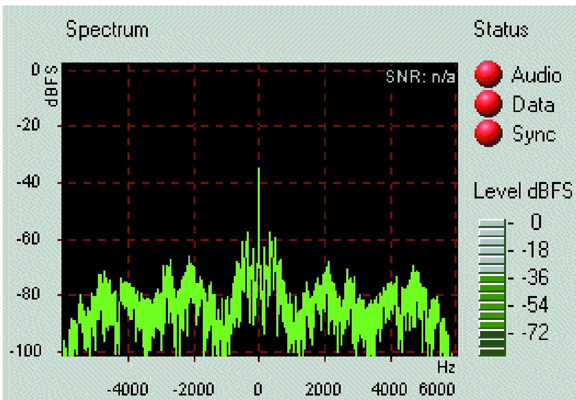


Figure 8. Using an AM broadcast station carrier as a frequency reference.

Decoder software

In addition to the tuning program DRM.exe (supplied by Elektor on disk or as a Free Download) you will require DRM demodulation/decoding software that works in combination with your PC soundcard. Two products are available on the market.

DRM Software Radio produced by the German Fraunhofer IIS (currently version 2.034) may be obtained at a cost of 60 Euros (approx. £43) from an online shop facility at www.drmrx.org. Payment for your order is by credit card. The download information and a software key arrive by email. The latest version supports the new MP4-based DRM standard introduced on 15 December 2003. Nearly all DRM stations now broadcast in stereo and achieve excellent sound quality using the new format.

The **DREAM** open-source project from Volkert Fischer and Alexander Kurpiers (a former Elektor author) of the Darmstadt University Institute for Communications Technology is currently available as version 1.0. The program is only supplied in the form of a C++ source code file because the authors have employed third-party modules that have to be obtained from the respective owners. The DREAM code itself may be found at

http://sourceforge.net/projects/drm/

The project may be compiled for Windows as well as Linux. If you are less than conversant with a C++ compiler, ask around for assistance with the creation of the files. DREAM_V1.0 has evolved into a serious alternative to the DRM Software Radio package. The program is stable and now presents less of a CPU load than before.
Meanwhile, the reception of pictures has become possible and the program is also capable of writing a log file containing reception reports. DREAM is very tolerant in respect of the exact frequency of the DRM baseband and will faithfully scan the complete range from 0 to 24 kHz. AM reception has been added as an extra mode, allowing the DRM receiver to be used for classic broadcast reception on the long- medium and shortwave bands.

In a future issue we will return to the DRM software decoder in greater detail. The DRM programs mentioned above are compatible with Windows 98 and up (i.e., 98, 2000, NT and XP).

Figure 9. GUI produced by the Visual BASIC example program written for the receiver tuning and station preselect functions.

ferred frequencies and they to are saved in the setup file. The file is editable using a word processor. So, if you (against sound advice) decide to overclock your DDS at 60 MHz, the new frequencies may be entered here.

Control using Visual BASIC

The PC-controlled tuning of the DRM receiver opens a lot of potential, including, for instance, labelled preselect buttons for your favourite stations, or timer-driven tuning to certain scheduled broadcasts. Moreover, the DDS may be used for measurement purposes. To give all readers maximum freedom in further experiments, the DDS control is explained here using a small example. The user interface produced by the example program is shown in **Figure 9**. The program employs one slider control, quick tuning buttons and two boxes for free tuning. Calibration facilities are not provided for the end user, the calibration being performed by constants hidden in the program.

The two decisive procedures of the program are shown in **Listing 1**. Using output (Data), 16 bits are shifted into a register inside the AD9835. The procedure LO computes the frequency and the required register contents of the DDS component. The output frequency is adjusted through a 32-bit value, the step size being 50 MHz/2^{32} = 0.01164 MHz. The allocation of thee regsisters and their addressing in the upper part of the 16-bit control word is detailed in the AD9835 datasheet. The program example shows the seven essential register contents needed to actually set the DDS frequency. A frequency 'word' is divided into four bytes conveyed to four partial registers.

Near the top of the source code you'll find two constants that have to be adapted to enable te frequency to be calibrated. The necessary data are taken from the ready-made user program for the receiver. XTAL = 50000 stands for the exact clock oscillator frequency, while IF1 = 455 defines the intermediate frequency. At a frequency of 466.3 kHz the IF becomes 466.3 kHz – 12 kHz = 454.3 kHz. The software controlling the RS232 traffic is a BAS module already described in [3].

(030365-1)

For further reading:

[1] 'Digital Radio Mondial', Elektor Electronics December 2002.

[2] 'An Experimental DRM Receiver', Elektor Electronics December 2003

[3] PC Serial Peripheral Design, parts 1-7, Elektor Electronics September 2000 – March 2001

Dave's Tower

Top Vertical is a Diamond X50A 2M/440Mhz , next one down is a 6M5X M Squared 5 element 6M beam, Next one down is a 2M9SSB M Squared 9 element 2M beam, next one down is a Cushcraft A3S HF Tribander for 20/15/10 Meters, the inverted vee off the side of the tower is my 30/17/12 M Inverted Vee.

Like all good things in life, a new antenna system with a tower begins with a hole in the ground. This hole measured 3' X 3' X 5' and was dug through three layers of calichi'. Calichi is a mexican word for "mud concrete". It is extremely hard and very difficult to dig with any known impliment. I used a post hole digger and a set of buckets. The system was to dig with the post hole digger until the buckets were full. Then climb out of the hole and carry the buckets to the back yard and dump them.

Needless to say it took me two weeks to dig the hole. Once the hole was done, then came the Rebar and the bolts. The bolts connect the concrete to the tower base and the rebar reinforces the concrete. The sheet from the concrete company says the materials to make the concrete weighed 7250 pounds before the water was added. That tower isn't going anywhere, unassisted.

Once the hole is filled with concrete then you can attache the base of the tower to it using the bolts that you placed in the concrete. This is where you find out how good your measurement skills have been. Luckily, my tower base fit perfectly on the bolts. and the tilt over base was mounted.to the concrete. From here on, the tower project was getting easier. The telescoping mast was attached to the base and the cables were hooked up and the mast section was raised to a upright position. The City inspector was called and the tower passed it's inspection. Next came the antennas, coax, coax arms, rechecking all the bolts were tight, and worrying about the winches being able to lift that load. But it all went up and up and up. The system seems to be working as now the DX stations answer me when I call them. Now it all seems worth while, but when I was digging that hole through the very hard clay, I HAD MY DOUBTS.

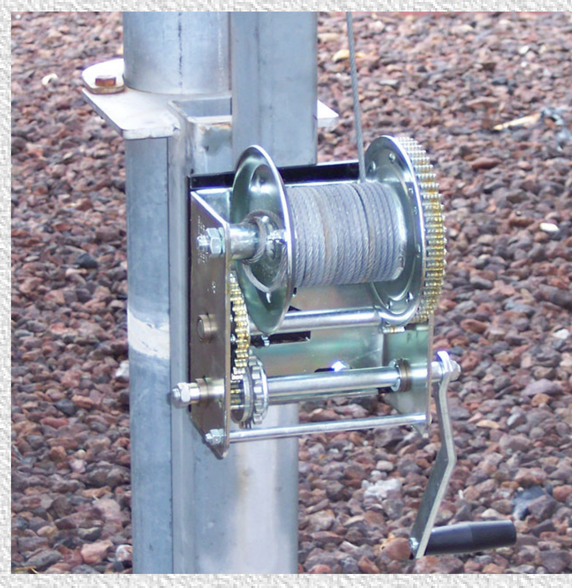
The Great Tower Modification:

My original lay over winch on my Wilson 40 foot tower was a Fulton KR1000 winch. It had been installed for about 25 years but still worked very well. The problem was that the

A new 15:1 ratio winch for the Lay over winch

The two pictures below show the new winch installation.

5:1 ratio was getting difficult for an "old man" to crank the tower over and back up. The modification consisted of buying a Fulton KR2500 braking winch and install in place of the KR1000. To provide extra support, a 1/4 inch piece of steel plate was mounted underneath the winch and on top of the lifting arm. The pictures below show the installation. It was the best thing I have ever done in that laying the tower down and up is much easier with the 15:1 ratio of the double action winch.



[Back to Main Page]

MK484 SHORTWAVE RADIO

TOM MERRYFIELD

Hit the shortwave trail with this two chip receiver

Although many a constructors have cut their teeth on building ZN414 radio circuits, the device, sadly no longer in production, now has a first class replacement in the MK484 a.m. radio chip.

The MK484 i.c. is a similarly three-pinned device with a.g.c. (automatic gain control) requiring only a few components to make a high quality tuner with a maximum supply voltage of just 1·8V. But that isn't all! The author was intrigued to see if it performed as well as its predecessor with the popular LM386 audio amplifier i.c. added to make a simple but effective shortwave radio project with loudspeaker output.

CIRCUIT DESCRIPTION

The results were quite surprising and the full circuit diagram for the MK484 Shortwave Radio is shown in Fig.1.

As with f.e.t.s, the circuit's high input impedance (several megohms!) is exploited to receive shortwave frequencies up to several megahertz (MHz), so long as the tuned circuit has negligible losses, thereby maintaining good selectivity.

The tuned circuit of the receiver is formed by L1, wound from 24 s.w.g. enamelled copper wire, and variable capacitor VC1. (For Cx and the aerial coil L2, see later.) Resistor R1 is needed to bias IC1, with capacitor C1 ensuring stability. As with other "front end'' tuner components these should be soldered close to IC1, with coil L1 and VC1 leads to the circuit board kept as short as possible.

Resistor R3 and capacitor C2 play an important role in setting the optimum gain for the MK484. In theory, the gain could be increased until instability results but there would be a loss in audio quality – i.e., more noise – well before this point. Hence the selection of R3 and C2 values.

Given that the maximum allowable supply to the MK484 should not exceed 1·8V, in conjunction with resistor R4, diodes D1 and D2 stabilise the voltage at about 1·5V. Due to the voltage drop across resistor R3, this falls to between 1·3V and 1·4V; a typically safe working voltage for the radio chip.

Capacitor C3 is needed to block d.c. getting through to the following audio stage, whilst coupling IC1's output signal to the LM386 audio amplifier IC2, via Volume conntrol VR1, at pin 3. Note also the bypass capacitor C4 preventing any stray r.f. from being connected to IC2.

From this point onwards the circuit is fairly typical with capacitor C5 setting the gain of IC2 and pins 2, 4 and 7 tied to ground, the latter via capacitor C6.

The inclusion of R6, C9, R5 and C7 prevents instability, thereby avoiding distortion in the output. In fact, the value of resistor R5 could be raised slightly higher to 18 ohms.

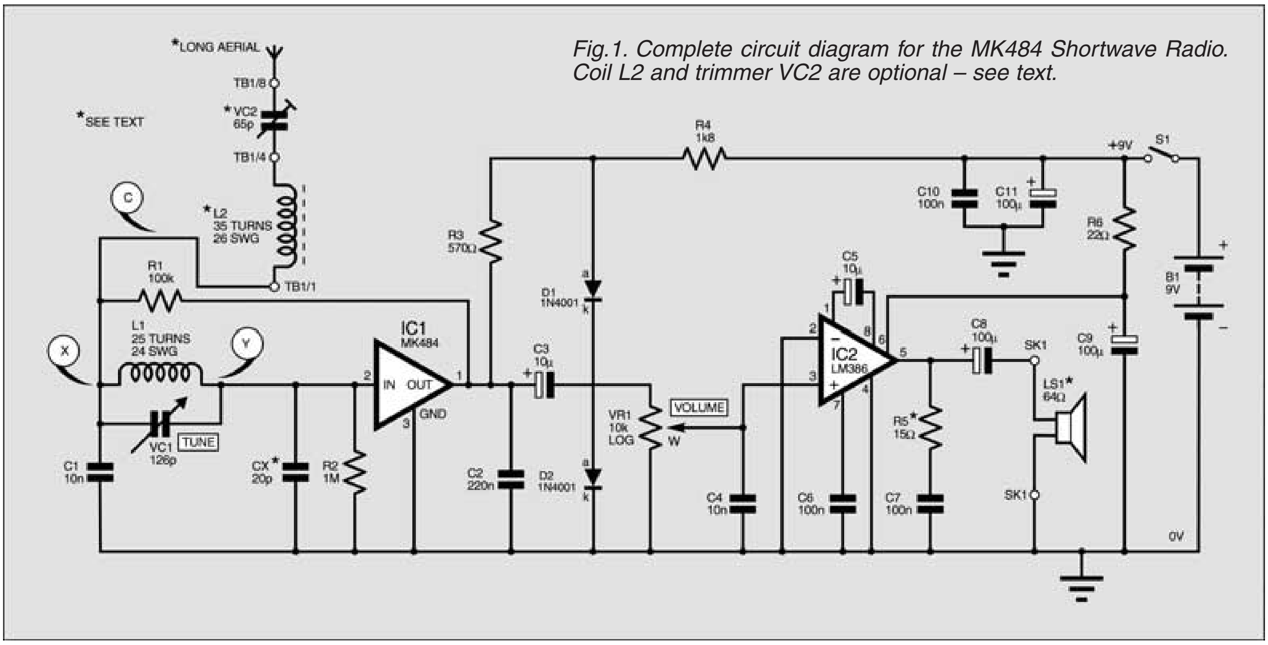


Fig.1. Complete circuit diagram for the MK484 Shortwave Radio. Coil L2 and trimmer VC2 are optional – see text.

With the output impedance being fairly low, a 64 ohm speaker gives a strong and even output but should be placed away from the tuned circuit area to avoid spurious feedback. For weaker signals however, Walkman type headphones can be used.

Q FACTOR AND AERIAL COIL

One point to bear in mind is that beyond 4MHz, losses in the tuned circuit heavily affect the selectivity. That is, the ability of a receiver to magnify a selected signal and reject others without an appreciable loss in gain.

In trials, the main coil L1 being loosely wound from 24 s.w.g. enamelled wire at 25 turns provided a suitable Q factor whilst still giving a broad enough tuning range.

As with most high gain devices at the front end, overloading tends to be a problem. This was certainly clear with the prototype. An ATU (Antenna Tuning Unit) would be ideal here in terms of matching the impedance of the aerial system and thus the signal to that of the receiver's input.

Failing that, an adequate measure is to connect up a long aerial lead via an aerial coil (L2) wound on a length of ferrite rod, and connected to the junction of R1, L1/VC1, via lead *C* (see Fig.1 and Fig.2.) This, in effect, provides additional tuning by sliding the aerial coil along the ferrite rod.

The long aerial itself can be any thin p.v.c. insulated connecting wire of 10 metres or so mounted as high as possible. For the most part this gives adequate results.

GETTING IN TRIM

In the prototype, a trimmer capacitor, VC2, was wired to the aerial circuit in series with the aerial coil L2 to give additional selectivity. With appropriate adjustment, this proved very effective in selecting individual signals from the crowded shortwave bands.

However, one precaution has to be observed; it is important to keep the aerial circuit and thus the aerial coil L2 well away from the main coil L1 and the receiver's input. Otherwise the signal can in effect bypass or "leapfrog'' ahead instead of passing through the aerial coil!

Although the prototype was built on stripboard, a terminal block is ideal for wiring up the aerial coil L2 and trimmer capacitor VC2 and divorcing it from the tuned input circuit (Fig.2).

As a rough and ready filter, polystyrene capacitor Cx is needed to subdue stronger signals. Although a 20pF capacitor has been quoted, any value from 20pF to 50pF can be tried. In case a polystyrene isn't available, a ceramic-dipped or multi-layered capacitor also works well.

COIL WINDING

Some readers may be surprised at home-made coils being used in the receiver as opposed to commercial types. In trials, these proved far more effective than the latter whilst being simple to make and inexpensive.

Unfortunately, a badly constructed coil can impinge on the performance by inhibiting the Q factor. On the other hand this can be easily avoided, the key being a good former and plenty of patience.

The former on which coil turns are wound can be a sheet of thin cardboard or gum paper about 40mm by 35mm wide rolled into a tube. Its diameter should be slightly larger than that of any ferrite rod/slab used so it can freely slide up and down. It is, therefore, a good idea to make this check before proceeding further.

It is also important to apply sticky tape *inside* as well as out. This keeps the former robust enough to withstand compressive stresses.

As for winding the turns, any difficulties can be avoided by handling the wire tactfully so it doesn't tie itself up in to knots. A good start is essential by securing the first few turns with insulation tape to prevent them from unwinding.

For the main coil L1, loosely wind 25 turns of 24 s.w.g. enamelled copper wire onto the carboard former, making sure there is a gap between most turns. Leaving short lengths at the start and finish of the coil for later attachment to the circuit board. Once completed, fasten the start and end windings with adhesive insulation tape and scrape the enamel coating off the end of the leads.

The aerial coil L2 should be made up of 35 turns of 26 s.w.g. enamelled wire more tightly wound with most turns touching. Once complete, check for any weak points and seal over with another applicatication of tape or wax. The enamel coating for the "tailends'' can be gently scraped off using sand-paper or emery cloth.

CONSTRUCTION

Despite employing quite a few capacitors, the receiver's simplicity means building it should not be too complicated a task.

COMPONENTS

Approx. Cost Guidance Only **£18** excl. speaker & case

Resistors

R1	100k
R2	1M
R3	570Ω
R4	1k8
R5	15Ω
R6	22Ω

All 0·25W 5% carbon film

See SHOP TALK page

Potentiometers

VR1	10k min. rotary carbon, log.

Capacitors

C1, C4	10n mylar poly. (2 off)
C2	220n mylar polyester
C3, C5	10µ radial elect. 25V (2 off)
C6, C7	100n disc ceramic, 5mm pitch (2 off)
C8, C11	100µ radial elect. 25V (2 off)
C9	100µ axial elect. 25V
C10	100n mylar polyester
Cx	20p axial polystyrene (see text)
VC1	126p min. a.m./f.m. tuning capacitor (ZN414 type)
VC2	5·5p to 65p min. trimmer

Semiconductors

D1, D2	1N4001 1A 50V rect. diode (2 off)
IC1	MK484 a.m. radio i.c.
IC2	LM386 low voltage audio amp.

Miscellaneous

LS1	64 ohm 0·3W loudspeaker (see text)
SK1	3·5mm mono jack socket
S1	s.p.s.t. toggle switch
TB1	8-way screw terminal block
L1, L2	tuning coils (see text)

Stripboard, 0·1in. matrix, size 50 holes by 15 strips; plastic case, size approx. 160mm x 90mm x 55mm; 24 s.w.g. and 26 s.w.g. enamelled wire for coils; ferrite rod/slab; 8-pin d.i.l. socket; 9V battery, with PP3 type clips; long aerial wire (10m p.v.c. covered connecting wire); plastic knob, 16mm skirted; 12·5mm long hexagonal spacer; M2·5 x 15mm screw; M4 x 30mm stud with nut (2 off); adhesive strips and card for aerial formers; solder pins; solder etc.

The prototype was built on a piece of stripboard measuring 50 holes by 15 copper tracks.

The topside component layout, interwiring and details of the breaks required in the underside copper tracks are shown in Fig.2. Commence construction by making all the necessary copper track breaks and inserting all the link wires (9 off).

This should be followed by inserting the resistors, capacitors, diodes and the two i.c.s. Care should, of course, be taken to ensure that diodes and electrolytic capacitors are inserted the correct way round. Wiring-up the aerial coils, volume control and tuning capacitor is carried out later when assembling the circuit board into a case.

Because the MK484 i.c. can be damaged by excessive heat, some form of heatsink is necessary during soldering. For instance, holding the device with metal tweezers to conduct the heat away whilst soldering it in; or attaching a croc-clip. An i.c. holder should be used for the LM386, IC2.

Once the soldering is complete, check for dry joints and tiny splashes of solder between tracks – the latter can be very easily missed, contributing to the "invisible short circuit" phenomenon. Also, double-check that all polarised components are correctly wired on the circuit board.

Prototype stripboard component layout.

As stated previously, the aerial coil L2 and trimmer capacitor VC2 should not be soldered directly to the board, but instead are wired via an 8-way terminal block. To help reduce losses at higher frequencies, keep the tuned circuit leads as short as possible.

TESTING

Although designed for shortwave use, the receiver can be easily tested in medium wave mode to see if everything works.

A pre-wound MW coil or one made from 30s.w.g. wire of 50 to 60 turns on a ferrite rod acts as the main coil for receiving MW frequencies. Also, no aerial, aerial coil or trimmer is required. If all is well, a strong and even output should be heard from the speaker or headphones at a half turn of the Volume control VR1.

CASING IT UP

Bearing in mind the prototype was used for the reception of high frequency bands with Walkman type headphones, the unit was cased in a box approximately 160mm × 95mm × 55mm high, without the speaker.

This kept things simple by using a 3·5mm mono socket for either headphone or a loudspeaker output. If preferred, a speaker could be mounted in a bigger case with a series of perforations over the speaker section.

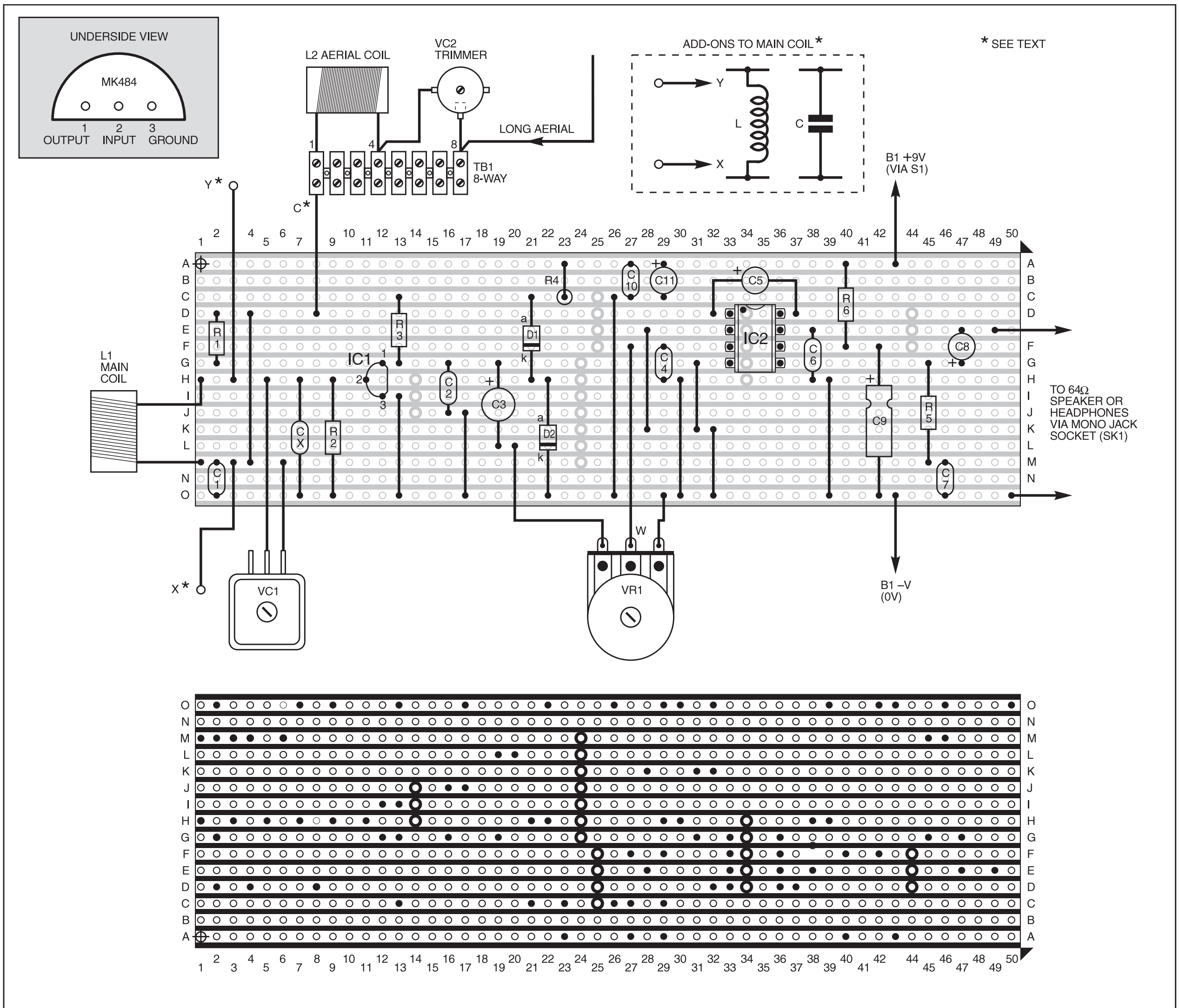


Fig.2. Stripboard component layout, interwiring and details of breaks required in the underside copper tracks. Pinout details (underside) for the MK484 radio chip are shown inset top left. Leads X and Y are for attaching additional tuning components.

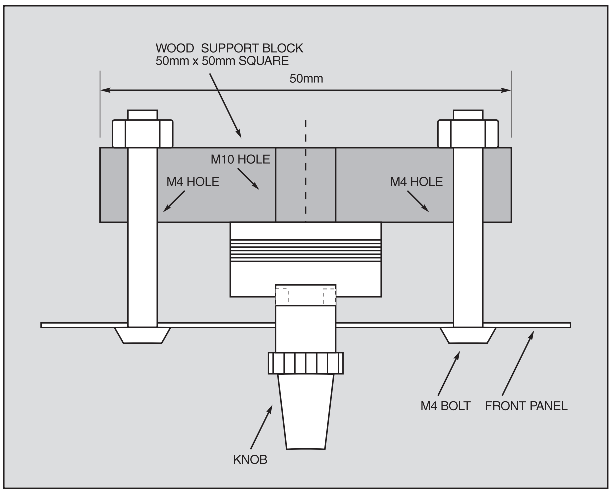
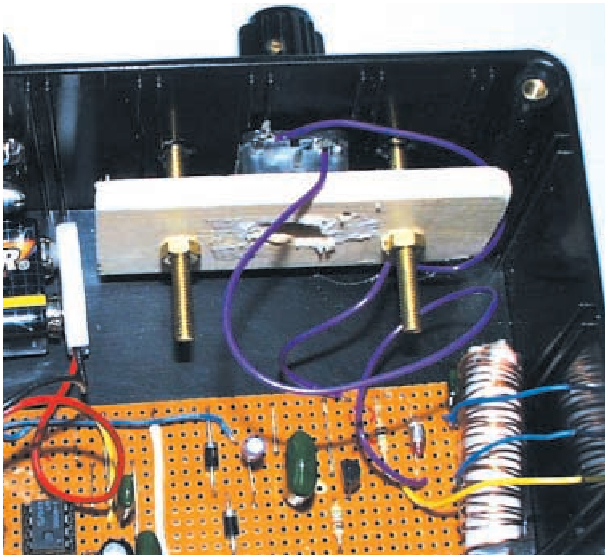


Fig.3. Suggested method of fitting the variable tuning capacitor VC1 to the front panel.



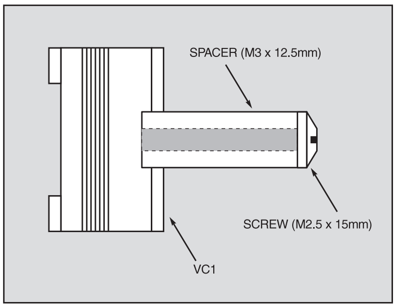


Fig.4. Lengthening the tuning capacitor spindle.

In terms of varying the frequency range, this can be achieved by adding a second coil or low value polystyrene capacitor in parallel with the main coil. Hence the leads *X* and *Y* in Fig.2. Given that the main coil L1 is soldered in-circuit, the "additions" can be wired up using a terminal block; as with the aerial circuit this is placed outside of the case. The circuit board and battery were simply affixed to the bottom panel of the case using adhesive pads.

TUNING CAPACITOR

More challenging is mounting the standard a.m. variable capacitor (VC1) securely to the panel. Basically, this isn't easy because of the tuner's dimensions, so a bit of improvising is needed.

As Fig.3 shows, a square offcut of thin wood or plastic measuring around 50mm × 50mm acts as a support to keep VC1 in place relative to the panel via M4 studs after drilling holes.

The problem of lengthening VC1's shaft is solved by using a hexagon spacer secured with an M2·5 screw of approp- riate length, see Fig.4. Care is needed here not to drive the screw too far into the capacitor, this risks damaging the vanes. A knob can then be attached, preferably with an adjustable grub screw fixing.

RESULTS

The prototype picked up many stations from all over Europe including Sweden and Denmark and several American religious broadcasts on the 41 metre band. The latter signals, however, required fine-tuning via the trimmer using a small screwdriver.

For higher frequencies, including the 25 metre band, little or no adjustment of the aerial coil may be needed. This includes broadcasts from China and many arabic stations including the United Arab Emirates.

Depending on atmospheric conditions and propagational effects, some fading of the signal is likely to occur at these frequencies. Of course, this happens with more complex receivers but to a lesser degree due to better signal processing and more stages.

That being said, Radio Korea, Turkey and Egypt were received loud and clear. Generally, the best time to try the h.f. bands is during the evenings when propagation conditions are better.

For those who would like to experiment, using different coils or varying the turns of the main coil always brings interesting results.

With practised intuition, plenty of signals can be tuned in, making the MK484 radio chip an impressive replacement for the ZN414. □

The completed prototype MK484 Shortwave Radio.

Radio Frequency Experiment by BH1RBG

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LiPo:Dummy Blance charger

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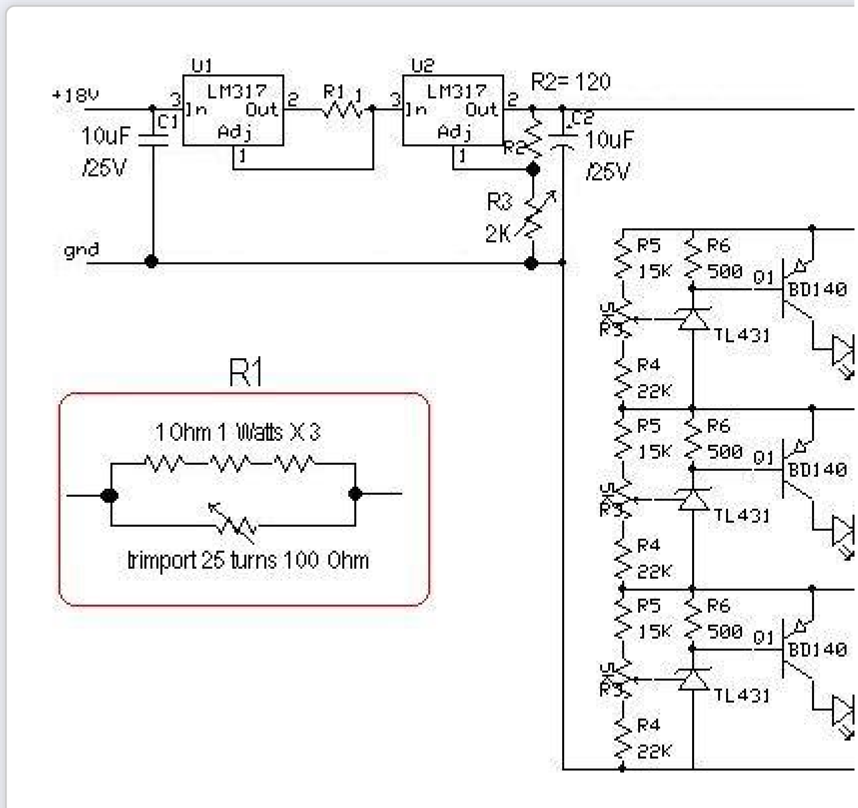
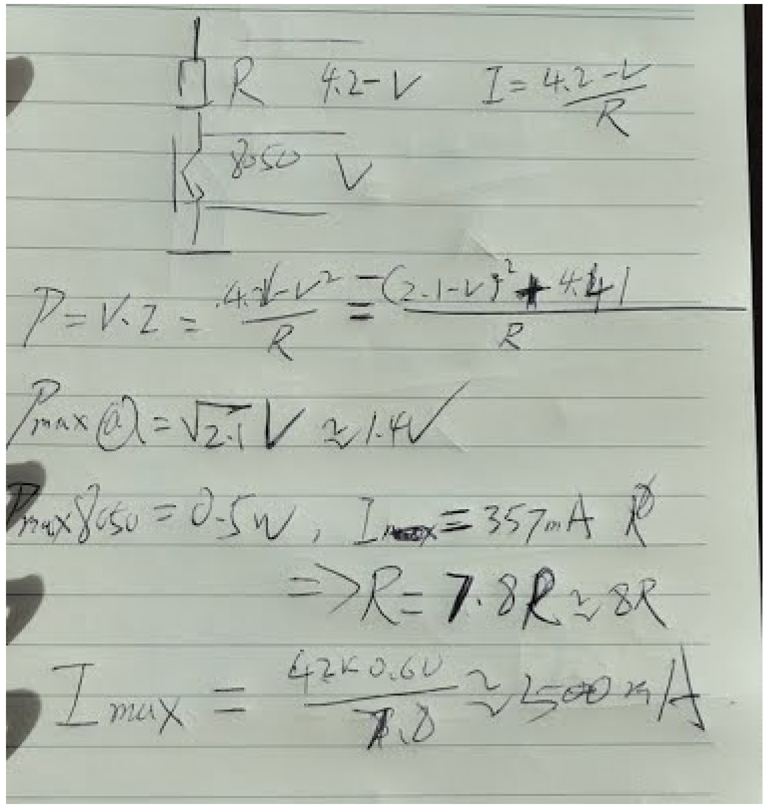
this balance charger very simple, use current pass by mode to balance the cell.



I redesign the charger to use 2sc8050 transistor, which is very very cheap.

Fuse based dead bug

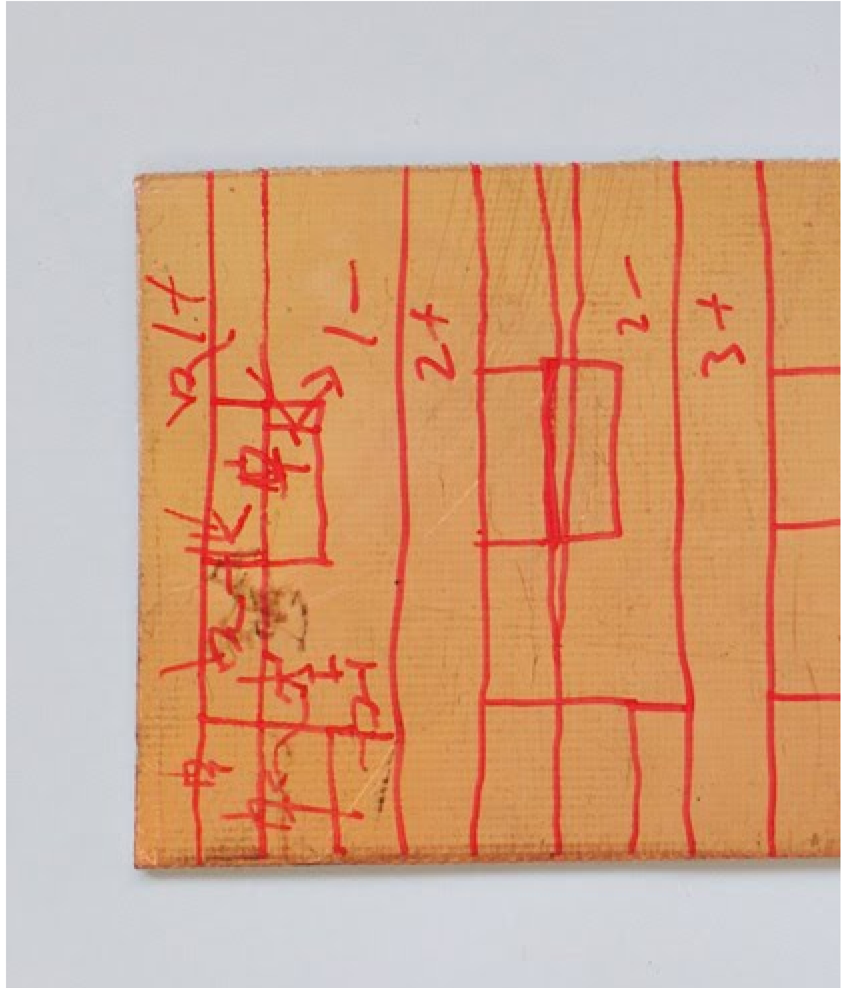
- RF Calculators
  - Heterodyne tracking calculator
- RF Experiment
  - AMP: Simple RF Amplifer
  - Antenna: JFET active attenna
  - Audio: 2 stages Transformer Audio PA
  - Audio: Discrete Power Amplifer
  - Audio: low distortion wein bridge
  - Audio: Pre-amplifer 2011
  - Audio: Push Pull PA
  - Audio: Simple power amplifier
  - Audio: wein sine bridge
  - Bias: favorite BJT/JFET bias guide
  - CXO: CXO/overtone for TX
  - CXO: Low distortion oscillator
  - CXO: Tune 5th Butler Overtone VHF Oscillator
  - Fail: CB Negistor-not work
  - IF: BJT 2 Stage with AGC
  - LiPo: Simple charger
  - Miller negative resistance Oscillator
  - Mixer: JFET active mixer
  - Oscillator amplitude stabilization
  - Ramp: linearity ramp genarator
  - Ramp: Versatile ramp generator
  - SA: What is SA (SA demo prj)
  - Supply: dual Li-Po 7.2V-8.2V
  - Sweep: Build new topology signal source
  - Sweep: simple Hartley Sweeper
  - VCO: Franklin 80Mhz-180Mhz
  - VCO: AM Hartley LO
  - VCO: CB colpitts 270Mhz-500Mhz
  - VCO: Improved Series E VCO
  - VCO: linearity factor
  - VCO: Negative resistance VCO
  - VCO: Negative VCO Linearity
  - VCO: Seiler 80Mhz-300Mhz
  - VCO: Ultra Negtive 100kHz-100Mhz
  - VCO: Vackar 30Mhz-240Mhz
  - VFO: ultra-audion LF to VHF
  - VFO: AM band Oscillator
  - VFO: hybrid feedback oscillator
  - VFO: Several Dipper Ocillators
  - VFO:New topology of Series-E oscillator
- RF Ham Radio
  - 10M:28.6Mhz FM transmiter
  - 27Mhz: AM RX/TX Experiment
  - AM: AM band transmiter by Techlib
  - Antenna: Your first Antenna



Quick prototype.

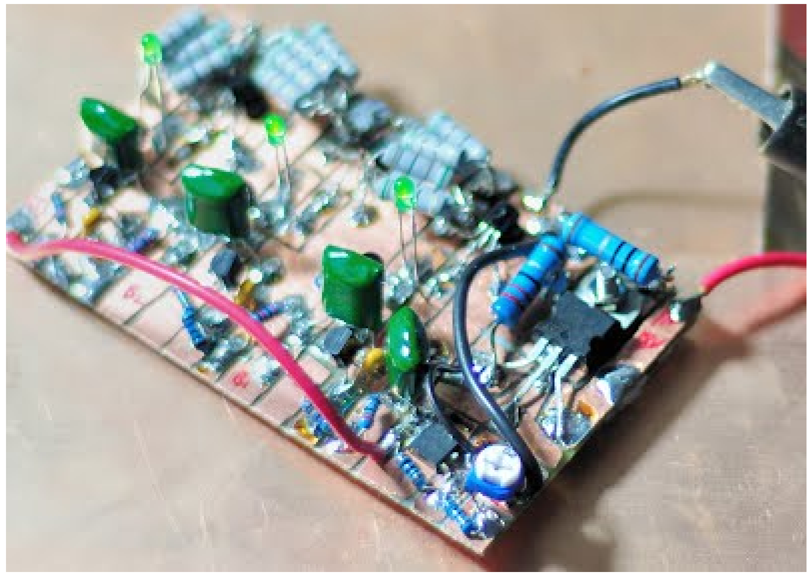
Contact me

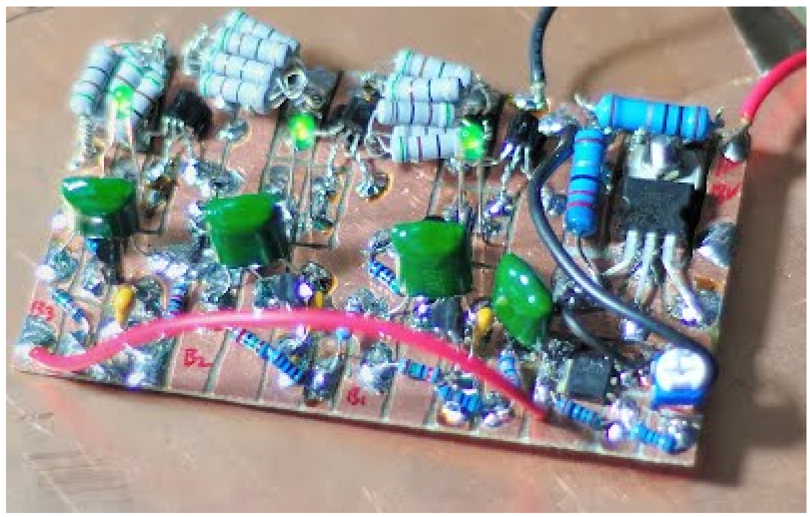
heyongli@gmail.com



Final board.


B3
B2
B1





Comments

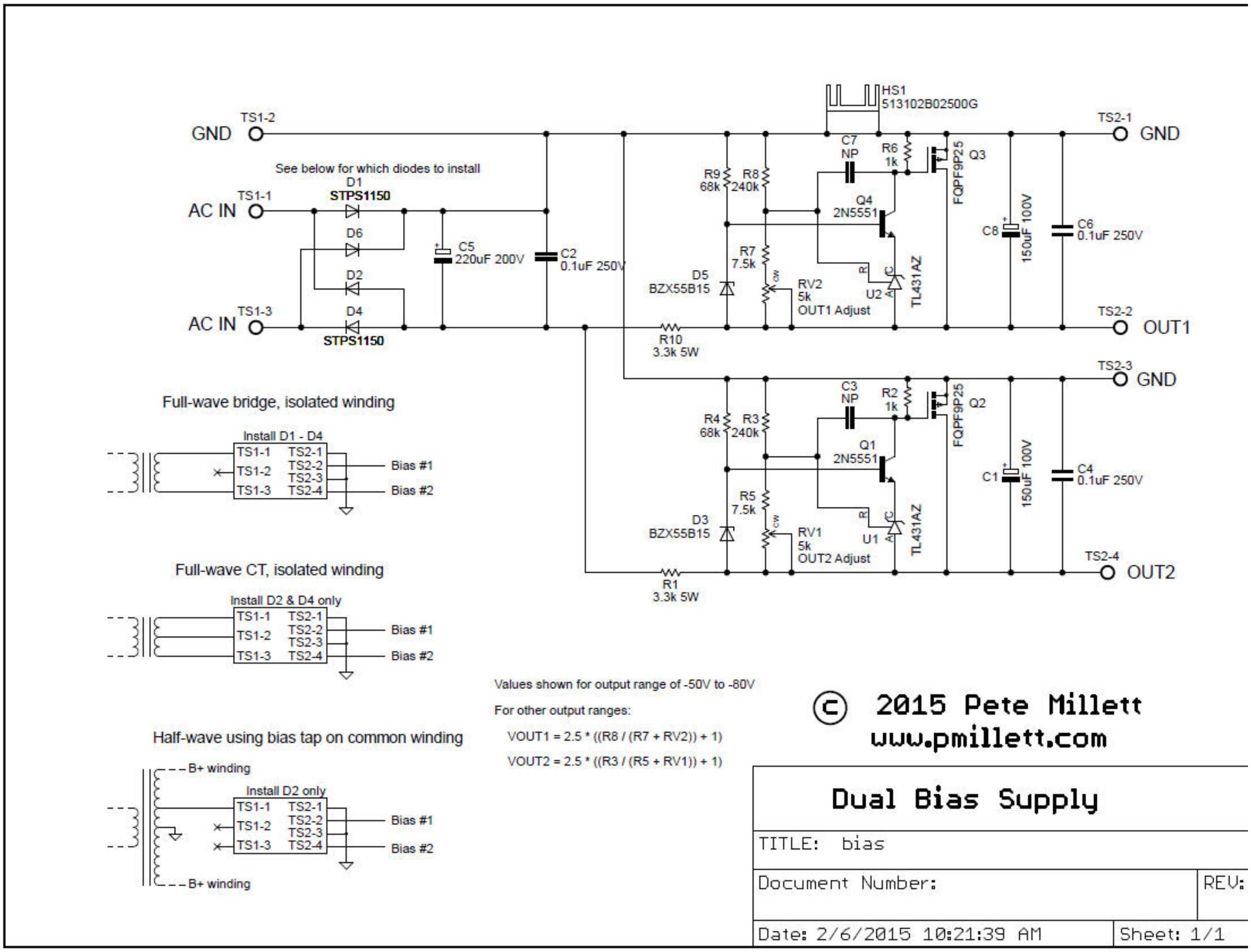
You do not have permission to add comments.

[DIY Audio Home](#)

Two-channel shunt-regulated bias supply

This is a two-output, shunt-regulated bias supply. I designed it for a push-pull 300B amp, but it can be used in any application where you need a regulated, adjustable negative bias supply.

Here is the schematic (or download it as a [PDF file](#)):



Note that the component values shown are for my application, which has ~100V RMS AC input and an output range of -50 to -80VDC (for 300B tubes). For other applications you will need to change component values. As shown on the schematic, the output voltage range is set by both fixed resistors and the adjustment pots. You can select the ratio of the pot to the resistor in series with it to set the adjustment range, and then set the upper resistor to get the output voltage you need. In any case keep the upper resistor (R3 and R8) above about 100k, so you do not burn too much current in the feedback divider.

There are several types of adjustment trimpots that will fit the PCB. The PCB has holes on 0.1" x 0.1" centers, which fit either 1/2" round or 3/8" square single-turn trimmers. You can mount them on the front or back of the PCB, depending on how you want to mount the board (I put them on the back so I can access them through a hole in the top of the chassis). I like the BI electronics "PR series", shown in the picture below.

Here is the parts list (BOM) for my application in [PDF](#) or [XLS](#) format. Again, you will likely have to change some resistor values for your application.

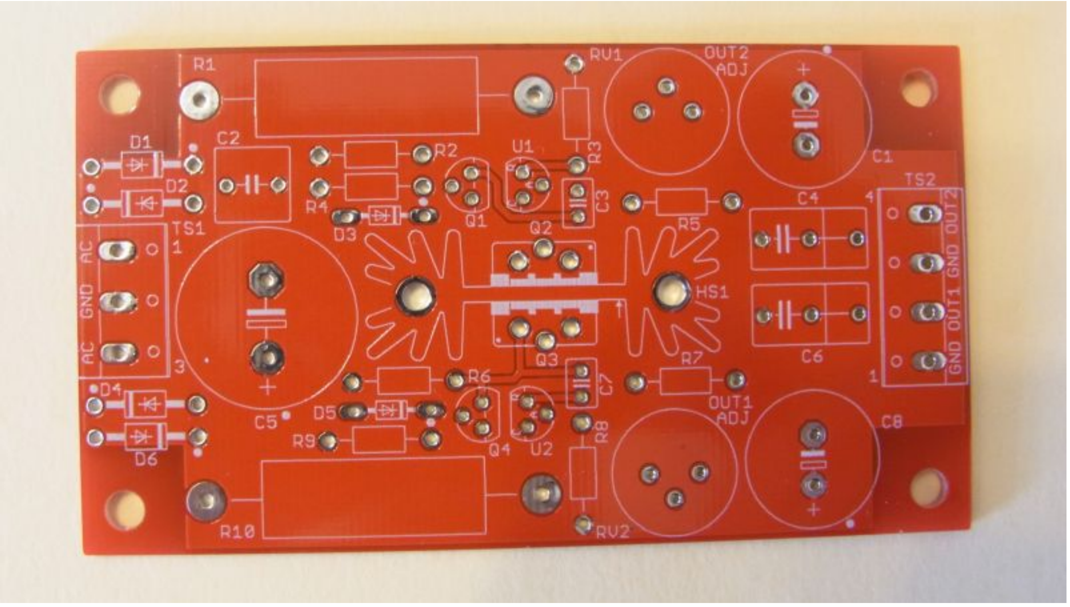
The series resistors (R1 and R10) set the quiescent current through the regulator. You want to keep a minimum of about 10mA flowing through the shunt regulator. So, if you have no output load current (as would be the case for a basic grid bias), pick a resistor so that the rectified DC voltage (using whatever transformer you are using) across C5, minus the desired maximum output voltage, gets you about 10mA. This value is not critical... more current will just cause a little more power dissipation in the FET and resistor. You need to keep under the resistor power rating (5 watt resistors will fit, maybe even some bigger ones), and the heatsink can dissipate around 4 watts (depending on how hot you're willing to let it get). You can use a taller heatsink if needed.

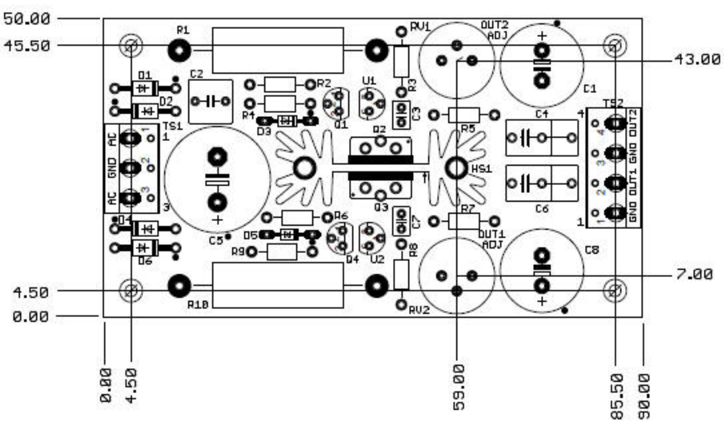
If you have DC output current (for example, you are using the bias supply for a CCS tail), you need to add that current with the 10mA minimum through the shunt. So, the series resistor would need to be smaller.

You need to have enough input voltage so that the regulator has headroom to operate. In other words, the series resistors need to drop some voltage. If the output voltage gets too close to the input voltage, the circuit will go out of regulation, and you'll get a lot of ripple on the output.

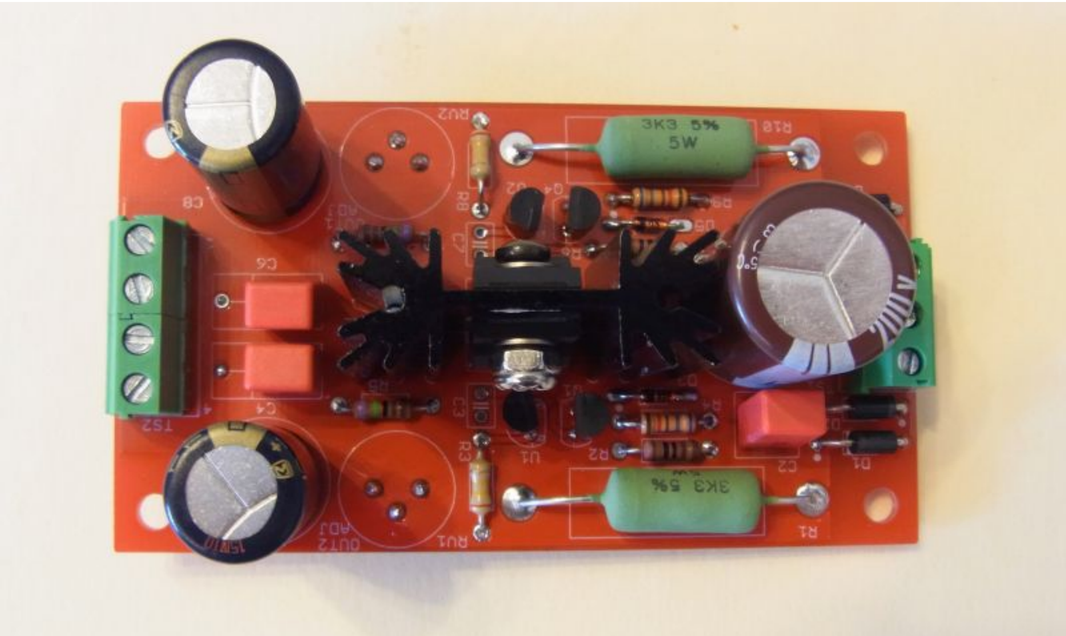
You can power the circuit with either its own transformer, using a FW bridge or FW center tap rectifier circuit, or from a bias tap on a power transformer with a grounded center tap using a half-wave rectifier. Refer to the schematic for hookup instructions. I would recommend using Duncanamps PSUD simulator to figure out the transformer and input rectifier circuit.

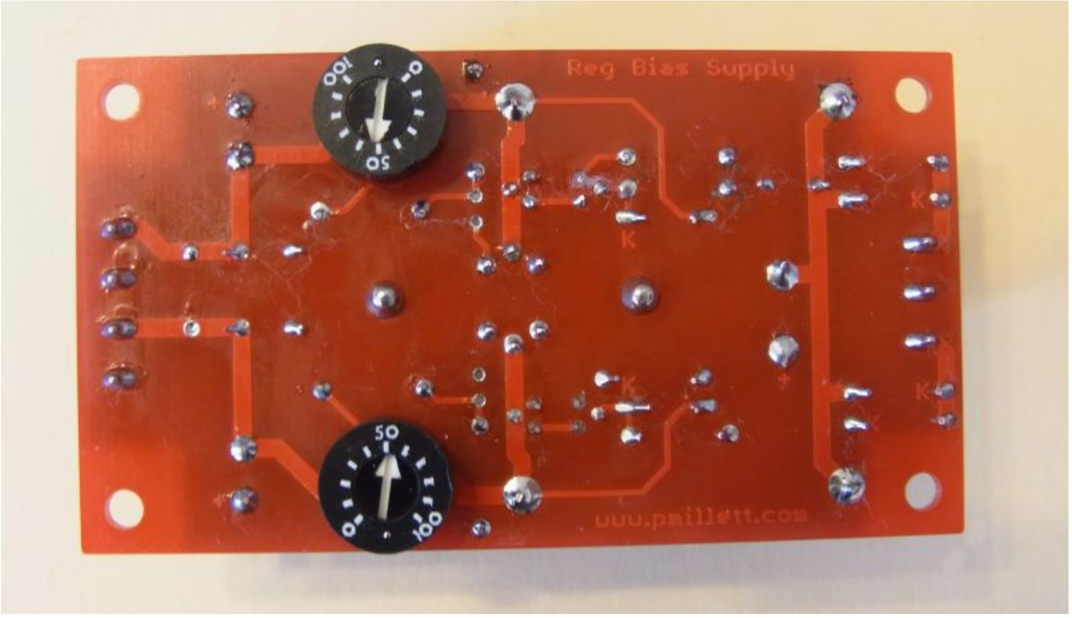
Here is the PCB, available on eBay:





The assembled PCB:

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Wireless Engineering and Technology, 2012, 3, 97-105
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A Wideband Circularly Polarized Patch Antenna for 60 GHz Wireless Communications

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ABSTRACT

This paper presents the design of a fully packaged 60 GHz wideband patch antenna incorporating an air cavity and a fused silica superstrate. Circular polarization (CP) is realized by introducing a diagonal slot at the center of the square patch. By optimizing the patch and the slot dimensions, a high efficiency (>90%) microstrip fed CP antenna with an impedance bandwidth of 24% and a 6 dB axial ratio bandwidth of 21.5% is designed. A coplanar waveguide (CPW) to microstrip transition with $\lambda/4$-open-ended stubs are then designed to match the antenna to the CPW packaging interface. The experimental results of the final packaged antenna agree reasonably with the simulation results, demonstrating an impedance bandwidth of more than 26% and a 6 dB axial ratio bandwidth of 22.7%.

Keywords: Patch Antenna; Circular Polarization; Millimeter Wave; Wireless Communication

1. Introduction

Demands of modern communication and sensor systems for more bandwidth, higher resolution and compactness lead to operating frequency up to the millimeter wave (mmWave, f > 30 GHz) or even sub-mmWave regime. In particular, the 60 GHz ISM (the industrial, scientific and medical) band is available in many countries. For example, in the US, the ISM band spans from 57 to 64 GHz with a worldwide overlap of 5 GHz of bandwidth for unlicensed use. As a result of the large bandwidth available, the 60 GHz band is very attractive for a number of applications, including wireless personal-area networks (WPAN) and local-area networks (WLAN). As the battery lifetime is a major bottleneck for many portable devices, the 60 GHz band has a distinct benefit because the large bandwidth can be utilized to tradeoff bandwidth efficiency for low power consumption, while still maintaining high data rate [1]. In addition, due to the atmospheric absorption (mainly oxygen molecules) peak around 60 GHz, communication link at this band is inherently secure and has less interference among users, which are ideal for indoor applications. However, at mmWave frequencies, higher material losses, fabrication tolerances and packaging issues often hinder the performance of wireless front-ends. Therefore, as an important front-end component, mmWave antennas that are wideband, efficient and packaged to be compatible with integrated circuits are highly desirable. Moreover, previous wireless channel propagation studies have shown that circular polarization can effectively suppress multi-path fading and inter-symbol interference (ISI) [2-4].

Various techniques to improve antenna performances such as bandwidth and efficiency have been reported in the literature. As shown in [5], cavity backing can isolate an antenna from its surroundings, suppress surface waves and increase antenna bandwidth. The detailed characteristics of various cavity backed antennas are summarized in [6]. Another approach to improve the bandwidth and efficiency of the conventional patch antenna is to minimize the substrate dielectric constant, as demonstrated in [7,8]. It is also known that the antenna gain can be considerably increased by covering the antenna with a high permittivity superstrate [9,10]. The fundamental effects of the substrate-superstrate structure on printed-circuit antennas are explored in [11], demonstrating that the antenna radiation efficiency can be optimized to approximately 100% by selecting the proper materials and dimensions of the substrate and superstrate.

All of the above mentioned techniques for improving the antenna performances can be applied in the mmWave antenna design. Several cavity backed wide-band antennas have been demonstrated in the V-band in [12-16]. In addition, metamaterial/EBG (electromagnetic band gap) based antennas with increased antenna gain have been reported in [17-21]. A good review of various mmWave integrated circuit antennas can be found in [22]. Fur-

thermore, several topologies of circularly polarized antenna have been proposed for the 60 GHz wireless communications [23-28].

In this paper, we present the detailed design of a 60 GHz left-hand circular polarized antenna [27] that has a good overall performance by combining various techniques reported in [5-16,29-31]. This patch antenna incorporates a diagonal slot at the center and features a superstrate and an air cavity backing to achieve desired performances including wide bandwidth, high efficiency and low axial ratio. The metal frame underneath the antenna layer serves as the cavity backing, useful for antenna bandwidth enhancement, as well as mechanical support for the antenna, making the antenna much more stable than using a supporting pin (only feasible at low frequencies) [7]. The microstrip-fed patch antenna is packaged with a flip-chip CPW interface that is fully compatible to semiconductor integrated circuits (ICs). In [29-31], linear polarized folded dipole antennas for 60 GHz applications using this superstrate/substrate topology and packaging scheme have been demonstrated. In this work, by optimizing the slot length of the patch antenna, a 6 dB axial ratio bandwidth of 22.7% is achieved, which is much greater than the 1.1% axial ratio bandwidth in [32]. Moreover, this antenna achieves a wide bandwidth of more than 26%.

A prototype antenna is fabricated and characterized using a probe-based measurement setup as described in [29]. The demonstrated patch has a dimension of 1050 μm × 1050 μm, while the final packaged antenna including feed lines has a dimension of 4849 μm × 5555 μm. Beyond the initial report in [27], the detailed design procedure of the circularly polarized antenna, including the design of the microstrip-fed patch antenna and the comparison of the performances of the antenna with different feeding interfaces, is described in this paper. The measured antenna efficiency is also obtained, demonstrating greater than 75% efficiency over the entire measured frequency range. In addition, the measured co-polarized and cross-polarized radiation patterns of the antenna are presented and compared with simulation predictions. Discussions on the measurement uncertainties that may explain the simulation/measurement discrepancies are included.

This paper is organized as the following. Section 2 introduces the antenna structures including its packaging. Section 3 describes the detailed antenna design procedures. The simulated (by finite-element electromagnetic solver HFSS) and measured antenna properties are compared in Section 4.

2. Antenna Structure/Packaging

Since packaging at mmWave frequency is challenging and critical to system performance [30], mmWave antenna designs should incorporate the packaging aspects as early as possible. The geometry of the entire antenna structure including its packaging is shown in **Figure 1(a)**, which consists of a top fused silica substrate (superstrate), a bottom air cavity made of copper and dielectric sealant encapsulant with a dielectric constant of 4 (ENC4) for further integration with flip-chipped ICs [30]. Similar package structures have been applied previously for folded dipole antennas and more detailed package design information can be found in [30,31]. The applied cavity size is optimized according to the antenna impedance bandwidth. The superstrate thickness T = 300 μm is a compromise since thinner fused silica samples would be difficult to manufacture and a thicker superstrate leads to reduced efficiency due to more energy staying in the dielectric layer as surface waves. All of the metallization (2 μm thick gold) of the patch antenna and its feed lines is on the lower side of the fused silica substrate, which has negligible loss tangent at 60 GHz and a relatively low dielectric constant of 3.8. To minimize the surface wave effects that can affect the radiation in the antenna plane, a gold ring is placed on the upper side of the fused silica. The fused silica substrate is mounted on top of an air cavity with copper walls, as shown in **Figure 1(b)**. The cavity has an internal size of 3890 μm × 3849 μm and an external size of 4890 μm × 4849 μm. The cavity height

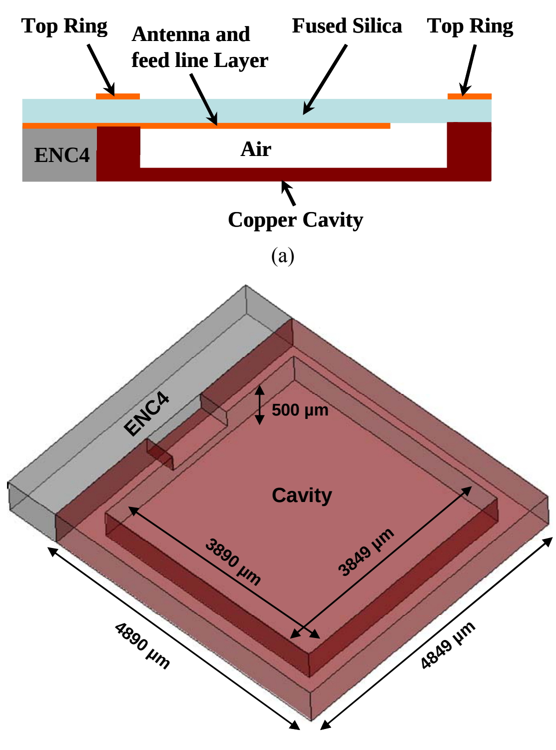


Figure 1. (a) The side view of the entire antenna structure; (b) The copper cavity.

is 500 μm, being the trade-off between the package size and the antenna bandwidth. The detailed parameters of the antenna structure and packaging are listed in **Table 1**.

The antenna structure shown in **Figure 1** has several advantages. First, a patch antenna at the lower side of the fused silica can be thought as having an air substrate with a dielectric constant of 1 and a superstrate with a dielectric constant of 3.8. These will lead to significant bandwidth and efficiency improvements compared with a normal one substrate patch antenna. In [31], a broadband dipole antenna for 60 GHz applications using a similar cavity and superstrate was reported. Second, this packaging scheme is fully compatible with flip-chip mounted monolithic integrated circuits such as an entire SiGe transceiver [30]. A schematic of the antenna flip-chip integrated with an IC chipset is shown in **Figure 2**.

3. Detailed Antenna Design

For the initial design, a microstrip-fed square patch antenna with a diagonal slot is applied to achieve left-hand circular polarization [32,33], as shown in **Figure 3**. The patch size is first selected to obtain a resonant frequency around 61 GHz and the microstrip line width is tuned to match the antenna impedance. The slot length mainly controls the circular polarization performance. It is observed that the frequency at which the axial ratio is minimum increases when the slot length C increases (10 GHz when $C = L/2$, 51 GHz when $C = L/1.1$ and 75 GHz when $C = L/0.9$), with the fixed patch size of 1400 μm and the slot width d kept at $C/10$ [34]. In addition, it is found that the slot length C also influences the antenna resonance frequency: the resonance frequency decreases when the slot length increases (with the fixed patch size and the slot width kept at $C/10$). **Figure 4** compares the simulated antenna reflection coefficients (S_{11} in dB) for different slot lengths with the square patch size $L = 1400$ μm. The antenna resonance frequency shifts from 62 GHz to 57 GHz when the slot length C increases from $L/2$ to $L/0.9$. The final dimensions of the patch antenna are optimized to make both the resonant frequency and the frequency with the minimum axial ratio at 61 GHz. The finalized design parameters are listed in **Table 2**.

The simulated reflection coefficients (S_{11} in dB) and axial ratio of the optimized antenna are plotted in **Figure 5**. It can be seen that S_{11} is less than –10 dB from 59 GHz to 75 GHz, with a bandwidth of about 24%. The axial

Table 1. Configuration of the antenna structure and packaging.

	Size (μm^2)	Thickness (μm)
Fused silica ($\varepsilon_r = 3.8$, tan$\delta = 0$)	4849 × 5555	300
ENC4 ($\varepsilon_r = 4$, tan$\delta = 0.02$)	4849 × 665	600
Air ($\varepsilon_r = 1$, tan$\delta = 0.0$)	3849 × 3890	500
Top ring (gold) (width = 500 μm)	4849 × 4890	2

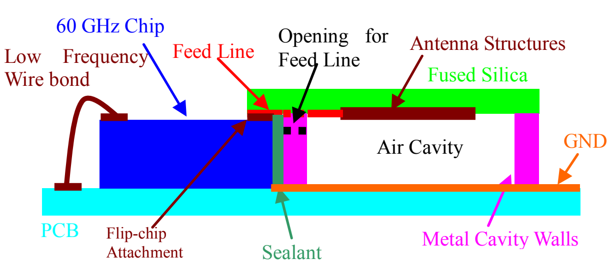


Figure 2. Schematic view of the antenna packaged with an integrated chipset.

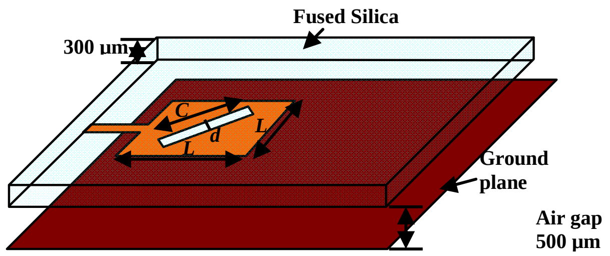


Figure 3. The microstrip-fed square patch antenna with a diagonal slot.

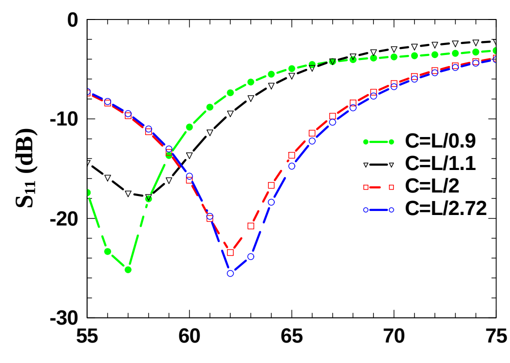


Figure 4. Simulated reflection coefficients (S_{11} in dB) of the square patch antenna (L = 1400 μm) with different slot lengths C (slot width $d = C/10$).

Table 2. The dimension of the finalized patch antenna design.

Antenna length	L = 1050 μm
Antenna width	L = 1050 μm
Slot length	C = 1141 μm
Slot width	d = 114 μm
Microstrip line width	W_0 = 400 μm
Microstrip impedance	Z_0 = 102 Ω

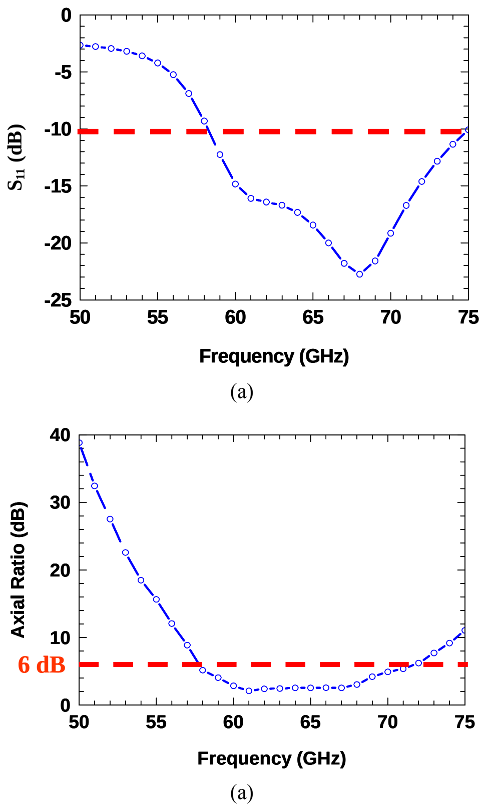


Figure 5. Simulated microstrip-fed square patch antenna performance: (a) Reflection coefficients (S_{11} in dB); (b) Axial ratio.

ratio is less than 6 dB from 58 GHz to 72 GHz, with a bandwidth of 21.5%. Comparing with conventional patch antennas, the bandwidth of the optimized antenna is much greater due to the utilization of the air cavity and the fused silica superstrate. The simulated antenna efficiency is higher than 90% for the entire frequency range from 50 to 75 GHz.

A CPW to microstrip transition is then designed to satisfy the CPW interface of the antenna packaging and enable convenient measurements using a CPW probe. The transition section is composed of a tapered microstrip line and a CPW line (labeled CPW4) with two approximately $\lambda/4$ open-stubs to achieve the desired grounding at the transition [35] around the center frequency of 61 GHz, as shown in **Figure 6(a)** with straight open stubs and **Figure 6(b)** with bent open stubs. The CPW4 section is designed to have the same impedance (102 Ω) as the microstrip. Two additional CPW lines (labeled CPW3 and CPW2) are used to transform the 102 Ω CPW line (CPW4) to the input 50 Ω CPW line (labeled CPW1).

To evaluate the impact of the CPW packaging, the HFSS simulated performances of the antennas with direct microstrip feeding, the CPW feeding with the straight open-stubs and the bent open-stubs are compared in

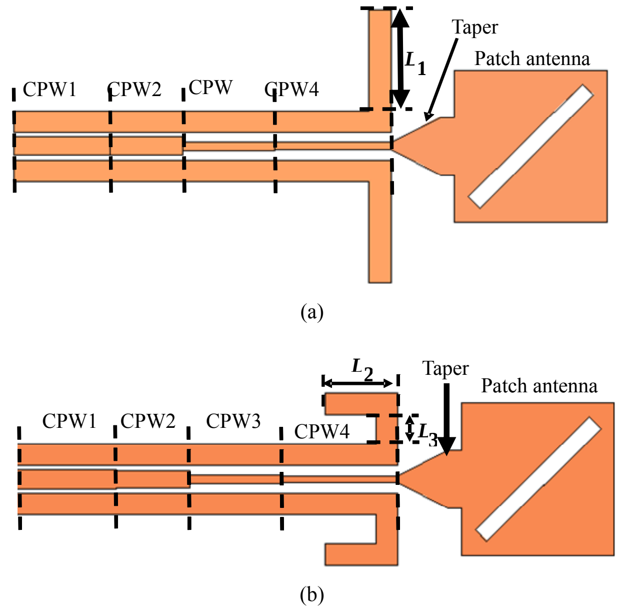
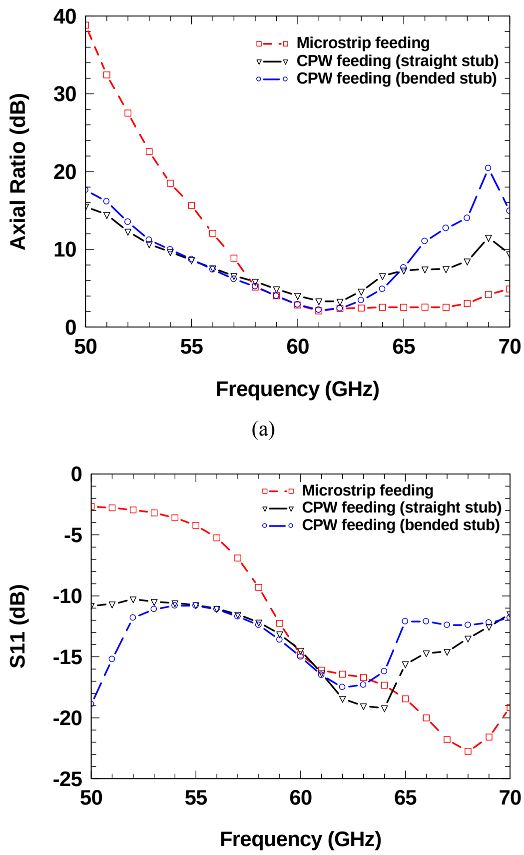


Figure 6. The top view of the antenna layer including (a) The CPW feed with straight open-stubs; (b) The CPW feed with bent open-stubs.

Figure 7. The simulated antenna efficiencies are greater than 90% for all the cases. The reflection coefficients and axial ratios of the three cases are similar at frequencies around 61 GHz (58 GHz - 64 GHz), as expected. With the CPW feeding sections, the antenna has a wider bandwidth and a narrower axial ratio bandwidth compared to those of the direct microstrip feeding. The S_{11} of the antennas with the CPW feedings are less than 10 dB from 50 GHz to 70 GHz with a bandwidth of 33%, which are larger than the 17% bandwidth of the antenna with the microstrip feeding. The 6 dB axial ratio bandwidths of the antennas with the microstrip feeding, the CPW feeding with straight open-stubs and bent open-stubs are 18.7%, 9%, and 9.9%, respectively. In combination, the bandwidth with both S_{11} less than –10 dB and axial ratio less than 6 dB drops from 17% to 9% and 9.9% when the CPW feeding sections are added to match the CPW interface, which is still sufficient for the applications at 60 GHz. In addition, the axial ratios of the antenna with bent open-stubs are around 1 dB lower than the case with straight open-stubs at frequencies around 61 GHz. Therefore, to reduce the impact of the $\lambda/4$ open-stubs on the radiation characteristics (especially the axial ratio) of the antenna, the bent $\lambda/4$ open-stubs are used for the final design. The final dimensions of the feeding sections are listed in **Table 3**, where L is the transmission line length, W is the transmission line width, g is the CPW gap, W_1 and W_2 are the widths of the two ends of the tapered microstrip. The widths of the two CPW grounds are 150 um each.



(a)

(b)

Figure 7. Comparison of antennas with different feedings (a) the axial ratio (b) the reflection coefficient (S_{11} in dB).

Table 3. The geometry of the CPW to microstrip transition.

CPW1	$L = 665$ μm, $W = 128$ μm, $g = 31$ μm
CPW2	$L = 500$ μm, $W = 124$ μm, $g = 33$ μm
CPW3	$L = 631$ μm, $W = 56$ μm, $g = 67$ μm
CPW4	$L = 800$ μm, $W = 50$ μm, $g = 70$ μm
$\lambda/4$ open-stub	$L_1 = 700$ μm, $L_2 = 500$ μm, $L_3 = 350$ μm
Taper	$L = 340$ μm, $W_1 = 50$ μm, $W_2 = 400$ μm
Microstrip	$L = 100$ μm, $W = 400$ μm

4. Comparison of Measurement and Simulation

To validate the performances of the designed 60 GHz left-hand circular polarized antenna, a prototype is fabricated by a thin-film resolution metal patterning process. The detailed fabrication procedure can be found in [30,31]. **Figure 8** shows a photo of the fabricated and packaged antenna. Note that the antenna layer on the bottom side of the fused silica can be clearly seen because of the transparency of the fused silica superstrate.

The antenna performances including return loss, axial ratio, gain and radiation pattern are characterized from 50 GHz to 65 GHz using a CPW probe based measurement setup in an anechoic chamber, as it is described in detail in [29]. To measure the axial ratio of the fabricated antenna, both a straight and a twisted waveguide adapter are used to feed the receiving standard gain horn. The challenge of the axial ratio measurement at 60 GHz is that it is very sensitive to the phases of the two polarizations. For example, when the straight waveguide adapter is replaced by the twisted one or vice versa, small misalignment would lead to the inaccuracy of the measured axial ratio.

Figure 9 plots the simulated and measured S_{11} of the fully packaged antenna (reference point at the beginning of the CPW line). The measured result indicates a 10 dB bandwidth greater than 26% (limited by the experimental frequency range), agreeing well with the simulation result. The measured axial ratio is plotted in **Figure 10**,

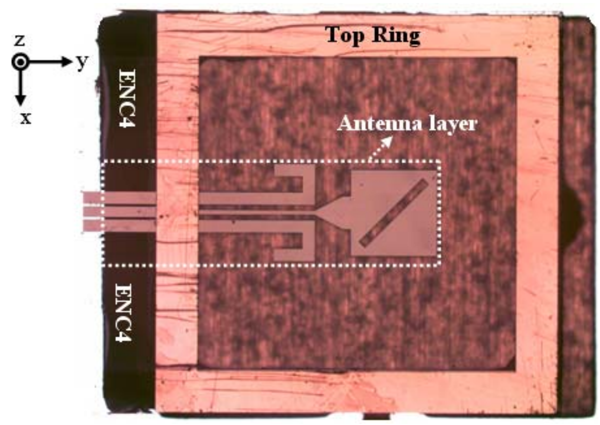


Figure 8. A photo showing the top view of the fabricated and packaged 60 GHz left-hand circular polarized patch antenna.

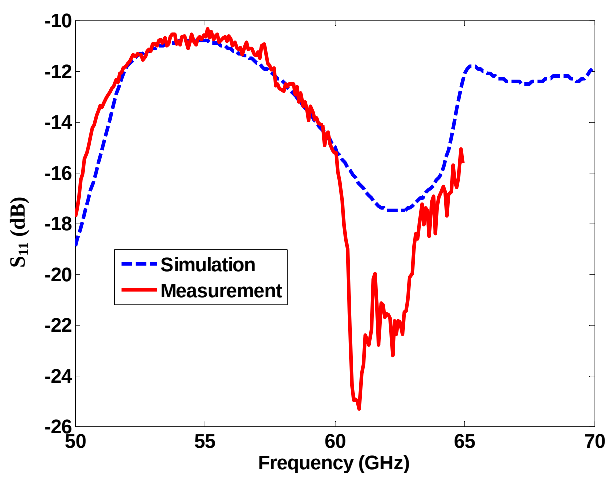


Figure 9. The simulated and measured reflection coefficients (S_{11} in dB) of the fully packaged antenna.

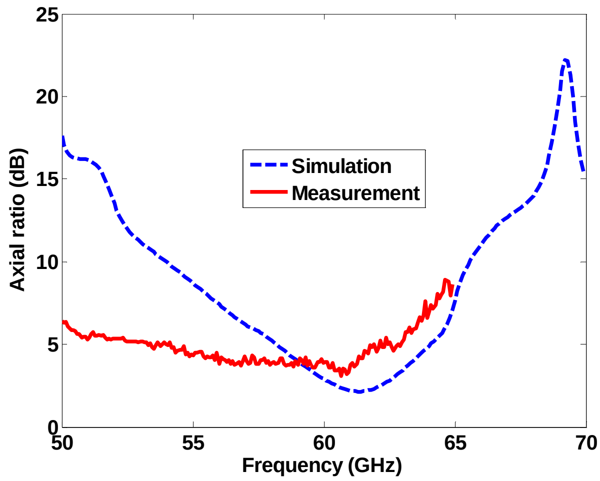


Figure 10. The simulated and measured axial ratio of the fully packaged antenna.

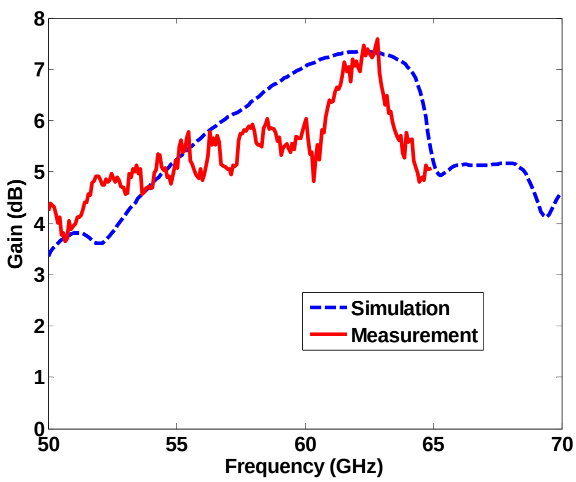
together with the simulated result. The simulated 6 dB axial ratio bandwidth is 9.9%, with a minimum value of 2.7 dB at 61 GHz. The measured minimum axial ratio (3.0 dB) also occurs around 61 GHz and the 6 dB axial ratio bandwidth is 22.7%. The measurement and simulation results agree well above 60 GHz but the measured values are significantly smaller at the lower frequencies. The discrepancy between the simulated and measured axial ratios is likely due to the measurement uncertainties discussed previously.

The radiation characteristics of the antenna are measured in both x-z and y-z planes (see **Figure 8**). The simulated and measured antenna gains (x-z plane) as a function of frequency are shown in **Figure 11(a)**. They match reasonably well with each other near the center frequency (at 61 GHz, the measured and simulated gains are 6.4 dB and 7.3 dB, respectively). The measured gain in the y-z plane (not shown) also has similar shape and range but is distorted a bit due to the interference of the antenna feeds in the measurement. Our simulation shows that the antenna efficiency is greater than 90% within the simulated frequency range, as the dashed curve plotted in **Figure 11(b)**. The measured antenna efficiency η_{mea} is then estimated as: $\eta_{mea} = \eta_{sim} * G_{mea} / G_{sim}$ (with the assumption that the measured and simulated directivities are consistent), where η_{sim} is the simulated antenna efficiency, G_{sim} and G_{mea} are the simulated and measured antenna gains, respectively. It can be seen from **Figure 11(b)** that the measured efficiency (solid curve) varies from 75% to 92% from 57 to 64 GHz.

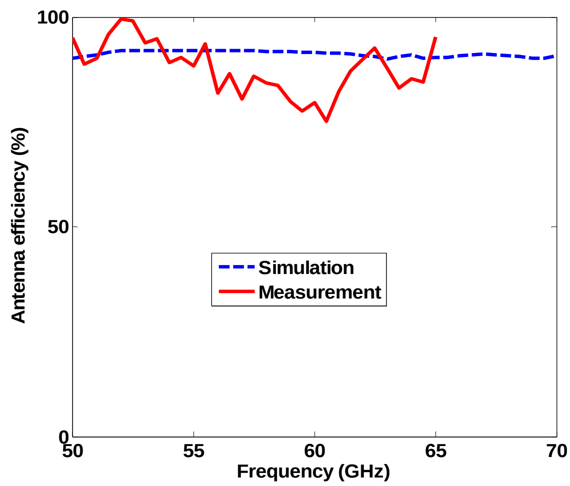
Finally, reasonable agreements between the simulated and measured radiation patterns in both the x-z and y-z planes are observed, as shown in **Figure 12**. The measured patterns away from the broadside in the x-z plane show some discrepancy, probably due to measurement uncertainties. The measured co-polarized and cross-polarized radiation patterns at 61 GHz are compared in **Figure 13**. One thing to notice is that the broadside gains in the y-z and x-z planes are different by about 1.4 dB. This discrepancy is also believed to be caused by experimental uncertainties.

5. Conclusion

A fully packaged left-hand circularly polarized antenna for 60 GHz wireless communications is demonstrated. Wide bandwidth and high efficiency are achieved by utilizing an air cavity and a fused-silica superstrate. The antenna packaging with a CPW interface is compatible to semiconductor integrated circuits. The measured antenna properties including return loss, axial ratio, gain and radiation patterns agree reasonably well with the simulation results. The demonstrated antenna achieved an impedance bandwidth greater 26%, a 6 dB axial ratio

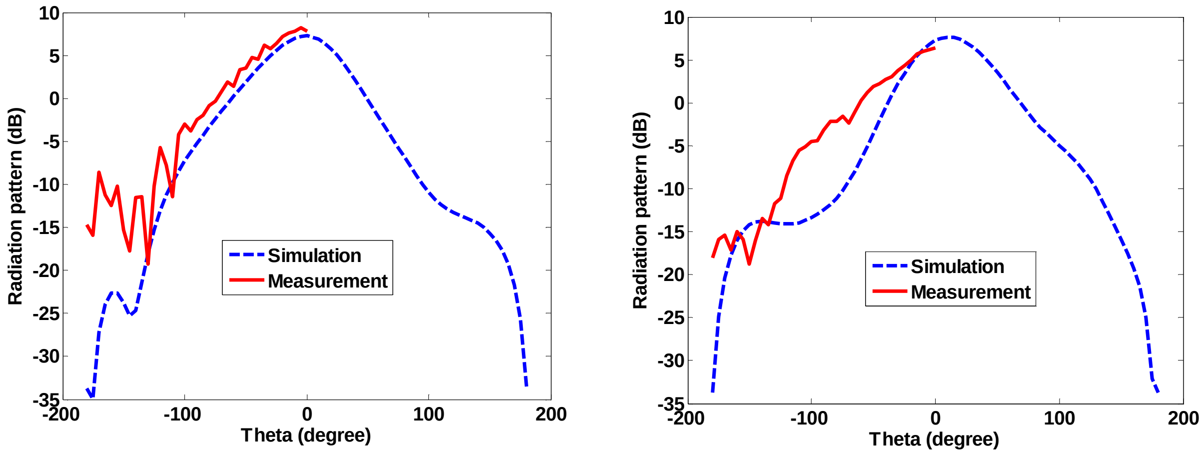


(a)



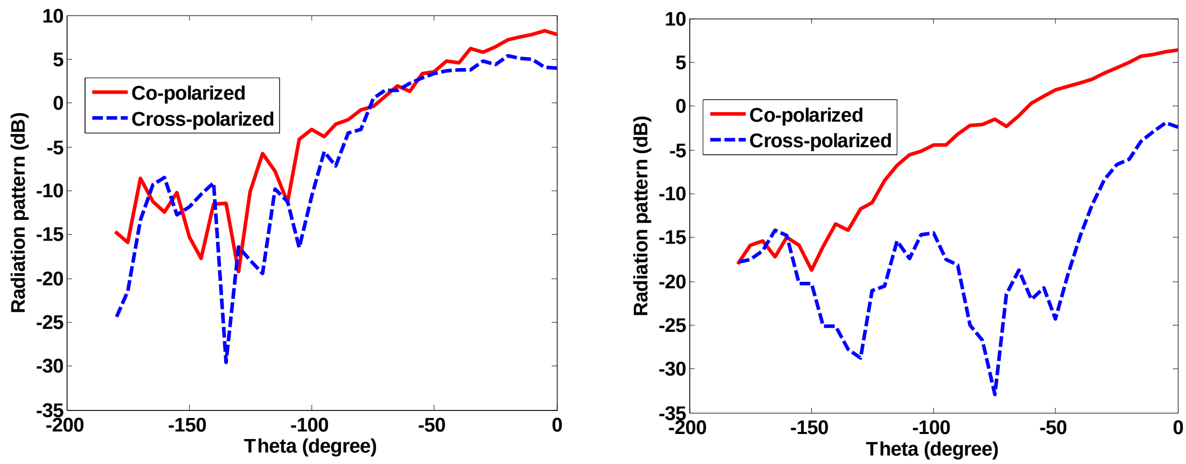
(b)

Figure 11. The simulated and measured antenna gain (a) and antenna efficiency (b) of the fully packaged antenna.



(a) (b)

Figure 12. The simulated and measured radiation patterns of the fully packaged antenna at 61 GHz in: (a) y-z plane; (b) x-z plane.



(a) (b)

Figure 13. The measured co-polarized and cross-polarized radiation patterns of the fully packaged antenna at 61 GHz in: (a) y-z plane; (b) x-z plane.

bandwidth of 22.7% and efficiency above 75% for the entire frequency range.

6. Acknowledgements

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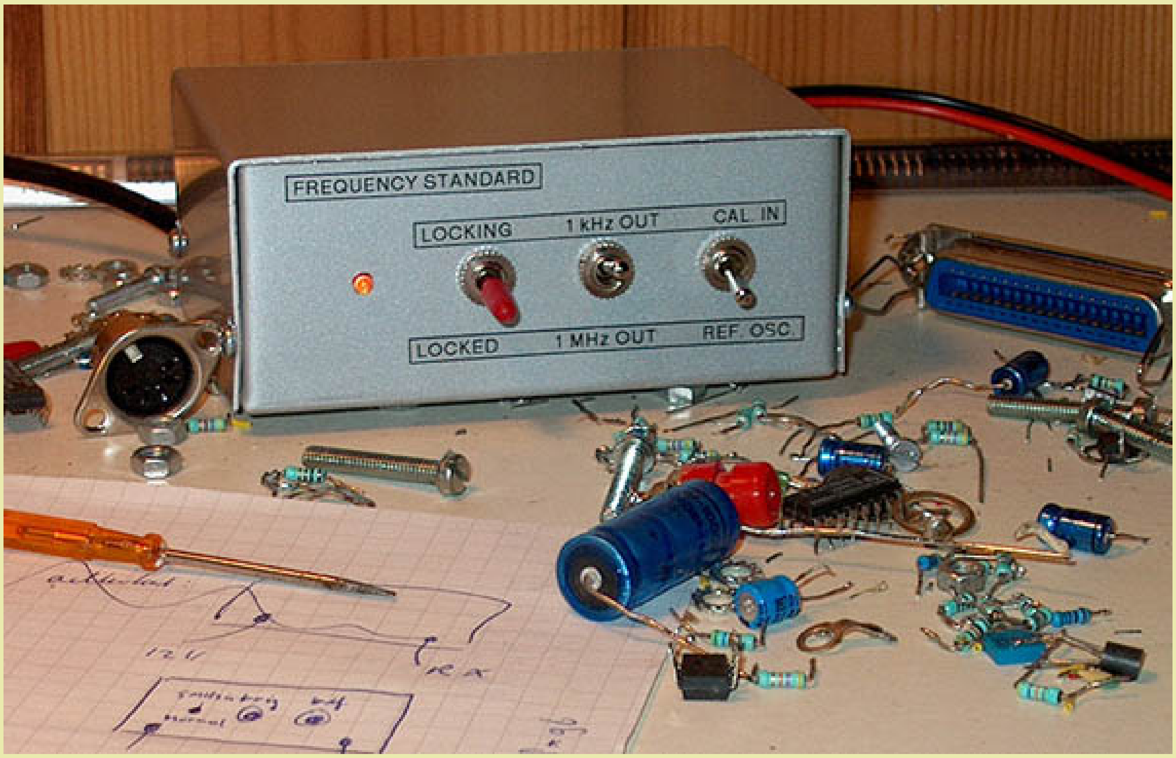
FREQUENCY STANDARD LOCKED AT DROITWICH ON 198KHZ

(1997 and 2007)

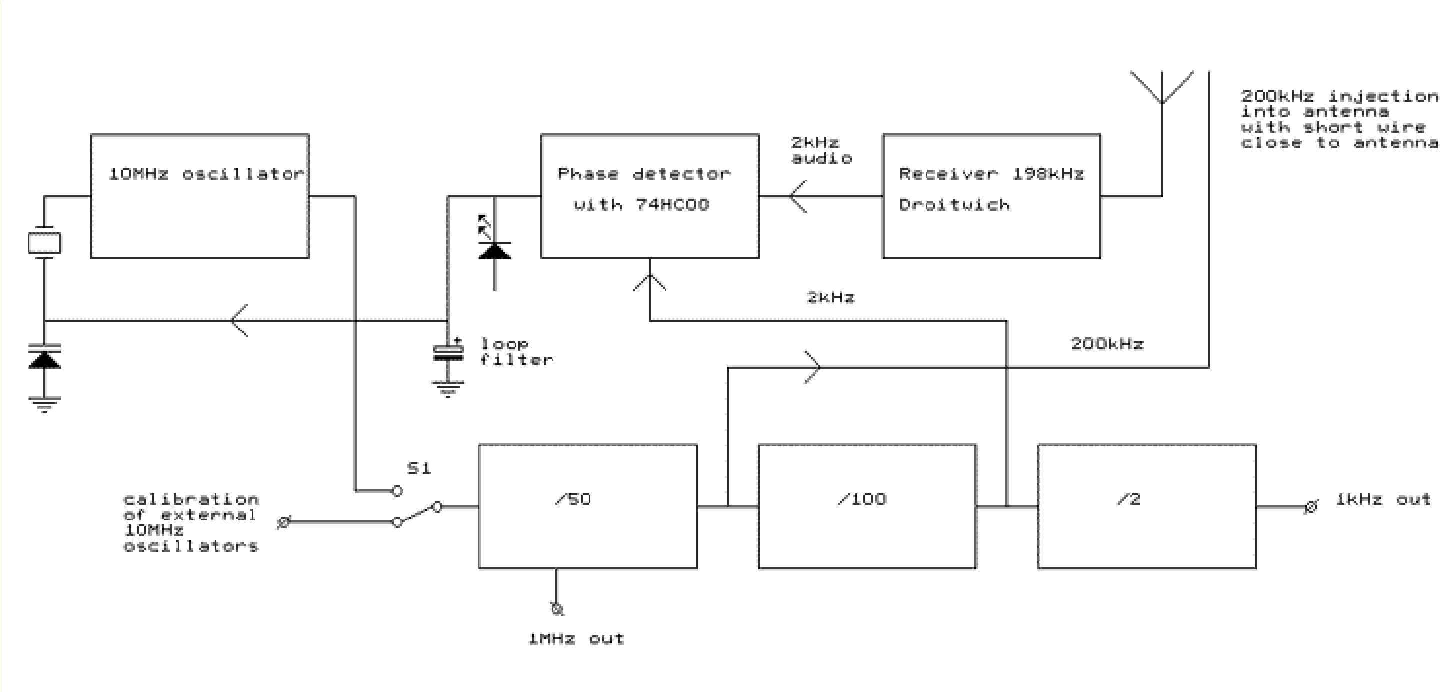
KLIK HIER VOOR DE NEDERLANDSE VERSIE



Frequency standard locked at Droitwich on 198 kHz.
And the remaining unused parts of the 1997 version.

Frequency standard locked at the longwave broadcast transmitter Droitwich on 198 kHz.
The Droitwich 198 kHz signal is broadcast by a BBC Radio 4 transmitter with a carrier power of 400 kW. The Droitwich station uses rubidium frequency standards and the fractional frequency offset typically observed is less than $10e^{-11}$ over a one day averaging period. For nothing we can lock our frequency standard at this very accurate signal!
It is not necessary to make a special receiver, a normal longwave broadcast radio can be used that is tuned on 198 kHz.

The first version was made in 1997. It was quite large, did not have the possibility to calibrate external 10 MHz oscillators and did have much useless electronics for decoding phase modulated data that is also transmitted. Decoding this data never succeeded. That is why in 2007 a smaller and simplier version was made with which also external 10 MHz oscillators can be calibrated.



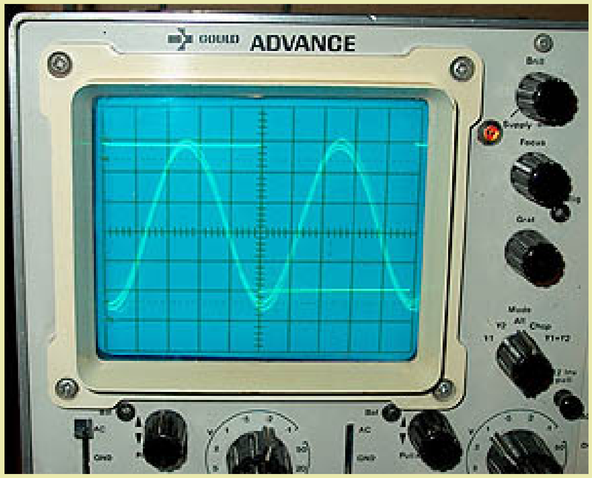
Block diagram of the frequency standard.

How does it work?
The signal on 198 kHz is received with an ordinary broadcast receiver.
The 10 MHz crystal oscillator is divided by 50 and by 5000 to obtain a 200 kHz and a 2 kHz signaal. The 200 kHz signal is injected into the ferrite antenna of the broadcast radio. Together with the 200 kHz signal, the 198 kHz signal of Droitwich will cause an interference tone of 2 kHz in the loudspeaker. This audio tone of 2 kHz is compared in a phase detector to the 2 kHz signal from the divider. When both 2 kHz signals are not exactly the same, the frequency of the 10 MHz oscillator is controlled.
The 2 kHz audio signal is filtered to suppress speech and music of the broadcast transmitter.
I did need an accurate 1 MHz signal and a 1 kHz signal. The 1 MHz signal is available on an output of one of the dividers, for the 1 kHz signal, the 2 kHz signal is divided by 2. But of course you can choose your own desired frequencies from the outputs of the various dividers.

A normal broadcast receiver is used to receive the signal on 198 kHz.

Calibration of external 10 MHz oscillators
To calibrate external 10 MHz oscillators, the switch S1 is set to the other position and the internal 10 MHz oscillator is replaced by the external 10 MHz signal. This oscillator is not controlled of course, we have to adjust it ourselfs. On the screen of an oscilloscope the filtered 2 kHz audio signal from the broadcast receiver is displayed. The oscilloscope is triggered by the 1 kHz signal from the dividers. The only thing we have to do now is to adjust

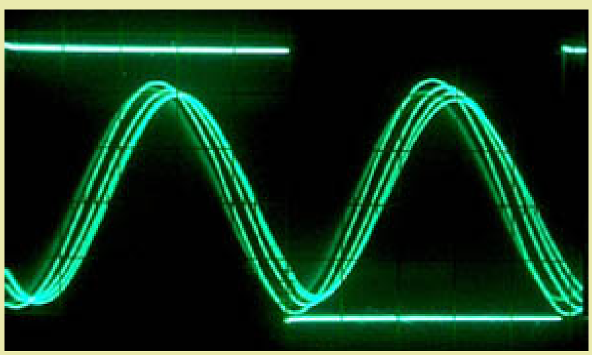
the 10 MHz oscillator so that the 2 kHz sine of the audio signal does not move to the left or to the right on the screen. When the sine moves one period in 50 seconds, then the error of the 10 MHz oscillator is approximately 1 Hz.



Calibration with an oscilloscope. The audio signal on the screen does not move to the left or right when the frequency is exactly 10 MHz. Triggering is done by the 1 kHz signal on channel 2.

Phase modulation of data signals

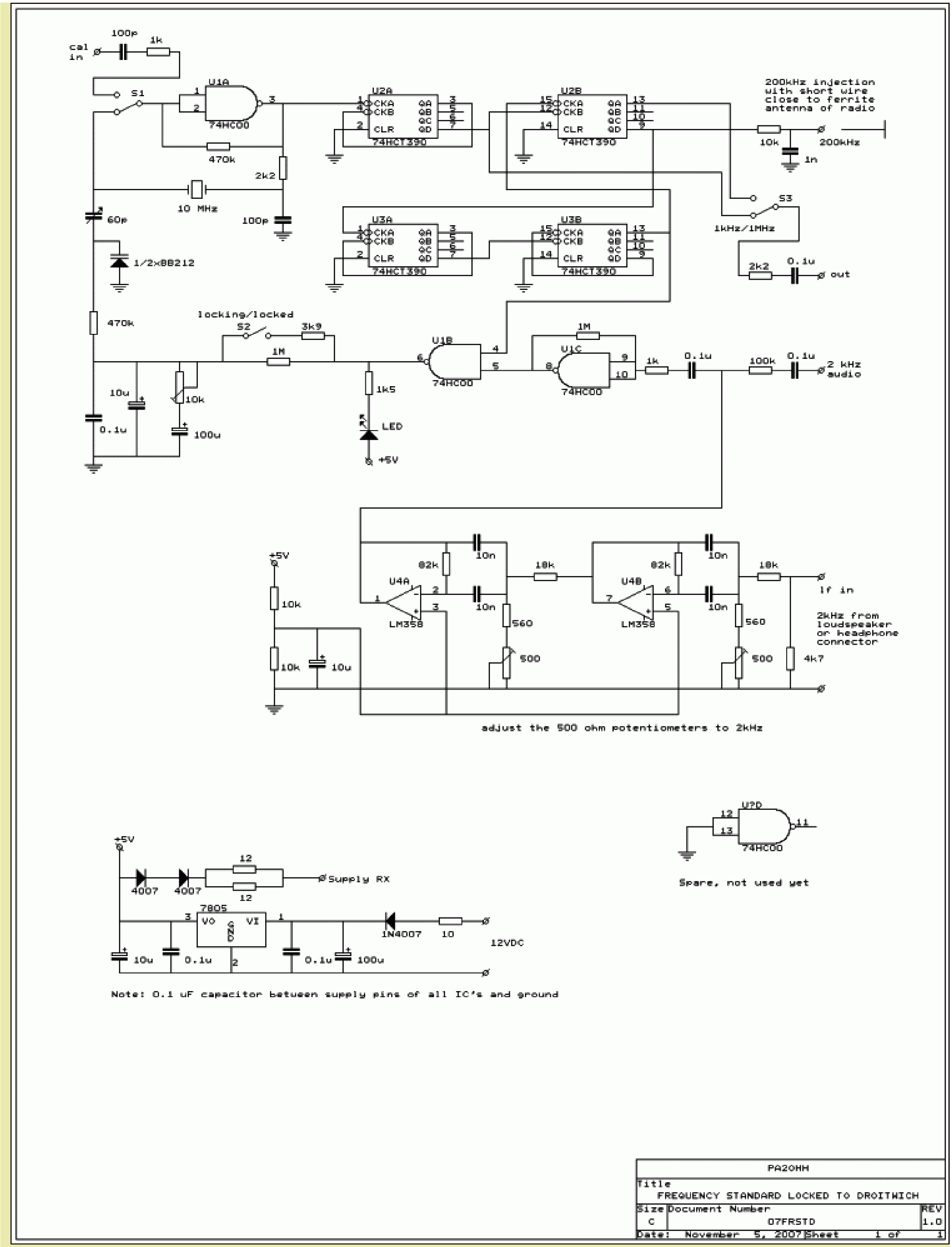
Unfortunately, we can not use the 198 kHz signal without any problem. It has phase modulation for the transmission of data. You can see that on the screen of the oscilloscope here below. The sine has jitter. This phase modulation has to be suppressed in the loopfilter of the frequency control, otherwise it will disturb the accuracy of the 10 MHz signal of the frequency standard. This can be done by making the loopfilter very slow. By doing so, the control loop will become also less sensitive for radio interference. The loopfilter in the circuit has two positions: a fast one to lock the oscillator and a slow one for when the crystal oscillator is locked.



Phase modulated data signals have to be filtered out in the loopfilter by making it very slow!

The diagram

Right above, you can find the 10 MHz crystal oscillator. With S1 you can select the internal oscillator that is controlled or for an external 10 MHz oscillator that has to be calibrated (adjusted). The internal 10 MHz oscillator is controlled by a varicap BB212 of which only one half is used. Both 74HCT390 are the frequency dividers, it are /2 and /5 dividers. The first divider is a /2 divider because I had once problems with a /5 divider that did not have a perfect square wave as input signal. A disadvantage is that the 1 MHz signal does not have a perfect duty cycle of 50%, because it is an output signal of a /5 divider. But that is not a problem for my application.
The 200 kHz signal is injected into the receiver with a short piece of wire that is mounted close to the ferrite antenna. So not a small loop around or close to the ferrite antenna, but capacitive coupling with a piece of wire, that does work much better.


cal in
100p
1k
S1
U1A
74HC00
U2A
CKA
CKB
CLR
QA
QB
QC
QD
74HCT390
U2B
74HCT390
200kHz injection with short wire close to ferrite antenna of radio
10k
200kHz
1n
470k
2k2
10 MHz
100p
60p
S3
1kHz/1MHz
U3A
74HCT390
U3B
74HCT390
2k2
0.1u
out
1/2xBB212
470k
locking/locked
S2
3k9
1M
U1B
74HC00
1M
U1C
74HC00
1k
0.1u
100k
0.1u
2 kHz audio
10u
10k
0.1u
100u
1k5
LED
+5V
+5V
10k
10k
10u
82k
10n
10n
U4A
LM358
560
500
18k
82k
10n
10n
U4B
LM358
560
500
18k
lf in
2kHz from loudspeaker or headphone connector
4k7
adjust the 500 ohm potentiometers to 2kHz
U?D
74HC00
Spare, not used yet
+5V
4007
4007
12
12
Supply RX
7805
VO
VI
GND
1N4007
10
12VDC
10u
0.1u
0.1u
100u
Note: 0.1 uF capacitor between supply pins of all IC's and ground
PA2OHH
Title
FREQUENCY STANDARD LOCKED TO DROITWICH
Size Document Number
C
07FRSTD
REV
1.0
Date: November 5, 2007 Sheet 1 of 1

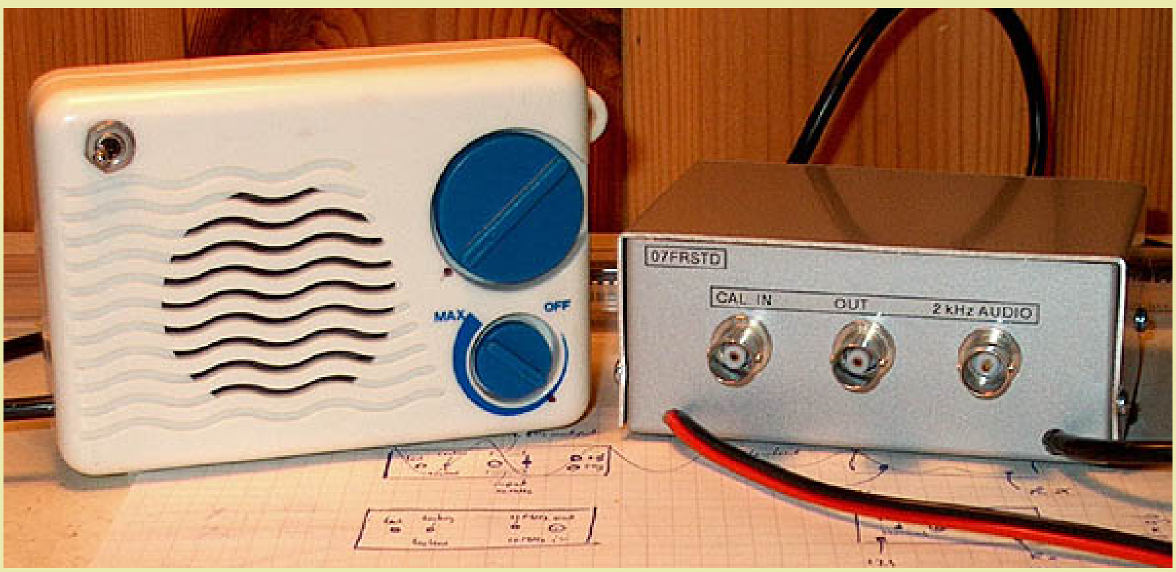
Diagram

[big diagram]

The 2 kHz audio signal of the receiver (headphones output) is connected to "lf in" and filtered in 2 active filters with a LM358. What remains is a good useable 2 kHz signal without interference of music and speech. Both filters should have a Q factor of 10 and a gain of 2x2=4x. With the 500 ohm potentiometers, they are exactly adjusted to 2 kHz. The filtered audio signal can be monitored with an oscilloscope by connecting it to "2 kHz audio".

The NAND U1C does make a square wave of the 2 kHz audio signal. U1B is the phase detector. The average value of the output voltage of this phase detector varies between 2.5 V and 5.0 V, perfect to control the varicap. Phase modulation and the 2 kHz square wave are filtered out in the loopfilter.

The loopfilter has two capacitors, one of 10 uF and one of 100 uF. The 10 uF capacitor removes the 2 kHz signal. With S2, the time constant of the filter can be selected for "locking" or "locked" or fast or slow. The loopfilter is too slow with the 1M ohm resistor to get the oscillator locked. When the oscillator is locked, the switch is set to the position "locked" and the 10 MHz oscillator is controlled very slowly. Phase modulation, the 2 kHz square wave and interference do have hardly any influence anymore on the stability in this position of the switch.
The stability of the control loop can be adjusted with the 10k potentiometer in series with the 100 uF capacitor. At 0 ohm, it will take much time before the circuit is stabilized, the frequency goes up and down very long. Also after interferences, stabilization takes a long time. With the potentiometer adjusted to 5k ohm, stabilization goes much quicker.
With the led you can check if the circuit is locked. If not, then the led goes slowly on and off with the frequency difference between both 2 kHz signals.
One NAND is not used, you can use that for example as a buffer after the crystal oscillator when you do need a 10 MHz signal.

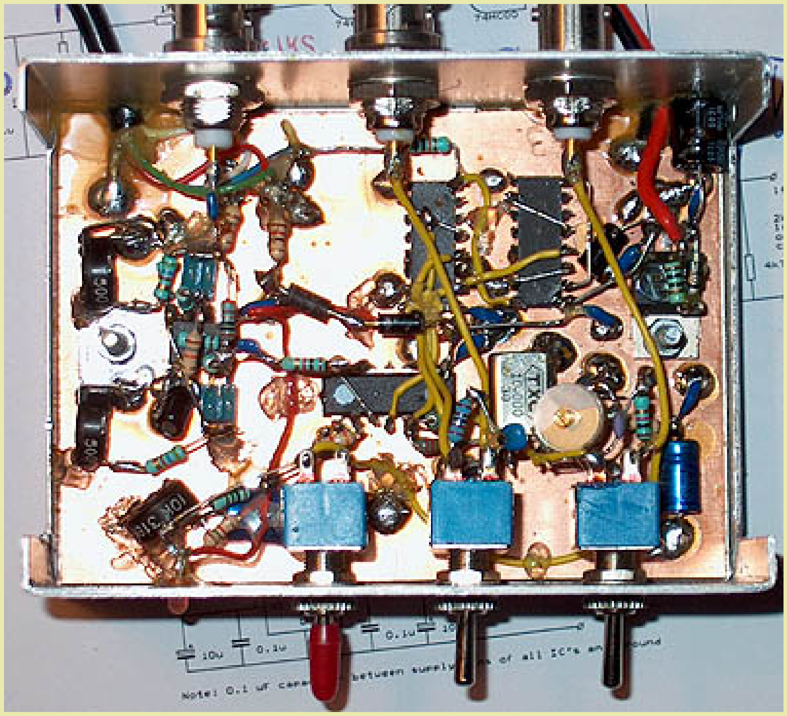


Rear view and modified medium wave receiver for the reception of Droitwich 198 kHz.

Modified medium wave receiver
The frequency standard worked perfect with the portable radio. But on a flea market, I did buy a small medium wave radio for only 0.50 Euro. It was modified for the reception of Droitwich on 198 kHz by placing capacitors in parallel with the two sections of the tuning capacitor. The 3 volt supply is taken from the 5 volt stabilizer of the frequency standard via two diodes to lower the voltage. The radio is permanently connected with the frequency standard by means of a 4 wire screened cable with a length of 1 meter. Supply, audio and the 200 kHz injection signal go through this cable. The loudspeaker can be switched on or off with a switch.

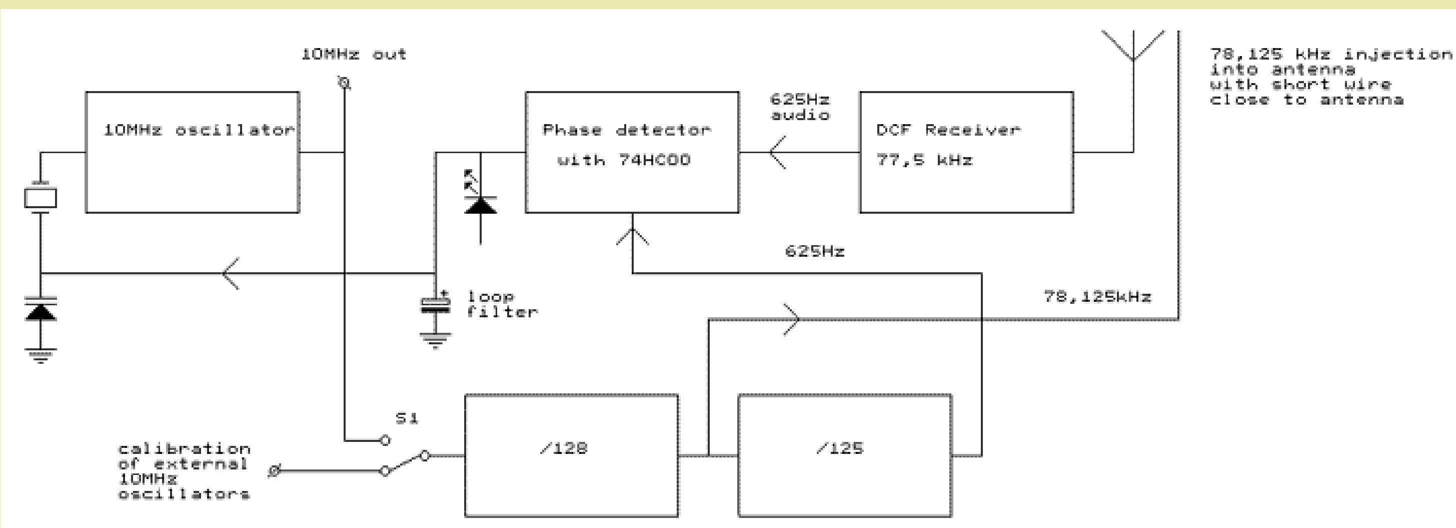
Results
A good impression of the accuracy can be obtained by comparing the 2 kHz audio signal with the 2 kHz (or 1 kHz) signal from the dividers with an oscilloscope. After that the control loop has stabilized, the variations during a few seconds are approximately 1/50 period. Or, the 2 kHz sine moves 1/50 period to the left or to the right during a few

seconds. This is difficult to measure because of the phase modulation. Variations are caused by instability of the 10 MHz oscillator, interference (fading) in the reception and modulation of the transmitter with speech and music. So the frequency error of the 10 MHz oscillator is less than 1 Hz. For us, radio amateurs, more than sufficient!



Inside view

For DCF77
Such a frequency standard can also be made for the German standard time and frequency transmitter DCF77 on 77,5 kHz. See here below for the principle that can be used.



Block diagram of a frequency standard locked at DCF77 on 77,5 kHz.

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A Mighty Simple Shortwave Transmitter

How many parts does it take to make RF? Seven if you're the Michigan Mighty Mite!

The Michigan Mighty is the name given to one of the most simple HF (a.k.a. shortwave) transmitters designed, which makes it an interesting project for both novices and hobbyists learning about RF fundamentals.

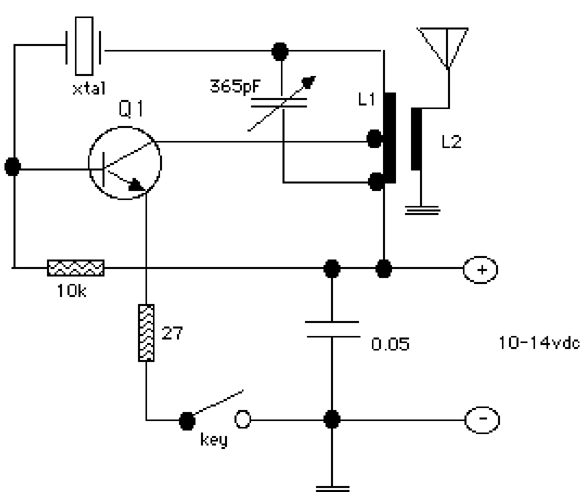
The history of this transmitter is a bit cloudy. It's generally credited to two hams: Ed Knoll, W3FQJ and Tom Jurgens, KY8I, but information about its origins is difficult to track down. One person on qrz.com claims to have found the exact schematic in an old magazine from 1977. This usenet post from 1994 has also been found. Another site discusses the origin as an article written by W3FQJ (no mention of the article name or publication) and was featured later in *The Five Watter'*, a newsletter produced by the Michigan QRP Club.

In general it doesn't really matter where it came from, so let's thank W3FQJ and KY8I and get on to building the transmitter!

This little circuit can put out about 1/2 a watt RF on 160, 80, 40 or 30 meter amateur radio bands (or any frequencies in between and close by, including the infamous shortwave pirate radio band found under the 40m ham radio band). The core of the design is a crystal controlled oscillator, which is fed into an RF output transformer, or *tank coil*.

Without any modifications, the basic design will allow for CW operation, but I will cover a few enhancements in subsequent posts that will allow for audio modulation and filtering.

The schematic is as follows:



Component list:

XTAL	This is your crystal that should be within one of the frequency ranges discussed above. If you don't have a crystal on hand, look at the links I mentioned here.

Q1	Use a 2n2219, 2n2222a, or 2n3053 transistor. Others may also work. I suggest using a TO-39 metal can style transistor, because this gets hot. If possible add a heat sink to it. If no heat sink is available, I've heard of people using an alligator clip attached to the top.
365 pF variable capacitor	Try one of the models I mentioned here if you don't have one on hand. Worse case, just take a few regular capacitors and place them in parallel until you are happy with the RF output. A variable capacitor is necessary though for optimal tuning of the circuit.
10k ohm resistor	A very common value
27 ohm resistor	A less common value, but easy to find. Or you can do what I did and chain three 10 ohm resistors in series. Whatever choice you make, the resistor value should be rated for at least 2 watts, so a single 2+ watt 27 ohm resistor works or a few 1 watt 10 ohm resistors will also work.
0.05 uF capacitor	A common value. If you don't have the correct value, chain a few lower value caps in parallel. **EDIT 2014-06-04:** Previously/incorrectly listed capacitor as 0.05 pF. The correct value is 0.05 uF.

L1 / L2 tank coil

	L1 (primary/collector windings)	**L2** (secondary/antenna windings)
160 meters	60 turns, tapped at 20	8 turns
80 meters	45 turns, tapped at 15	6 turns
40 meters	21 turns, tapped at 7	4 turns
30 meters	15 turns, tapped at 6	4 turns

Creating the Tank Coil

The tank coil diameter should be around 1.25". If you have a spare prescription bottle or film canister, either will work well as an inner form to wind your wire around. Remember to use a non-conductive form (e.g. plastic or wood).

Use #20 - #22 gauge magnet wire to construct your coils. If you don't have any, Radio Shack sells magnet wire, and you can pick it up on Amazon and a number of other places.

The tank coil essentially is comprised of two inductors (L1) that work within the oscillator circuit collecting magnetic energy. This energy is transferred in the form of RF to L2 at a 50 ohm impedance.

To wind the tank coil, start with L1, winding clockwise to the number of turns until the *tapped at* number. Create the tap by making a loop an inch long, twisting it a few times to hold it in place. Continue winding clockwise until you reach the total number of turns. Sand off the enamel from each end of L1 and on the center of the tap. I usually use a lighter to burn the enamel a little then use an X-Acto knife to scrape it off. Whatever your technique, remember that it needs to make good electrical contact in your circuit. Tape L1 together when you are satisfied.

Here is an image of what L1 looks like wound on a form:

The inch long wire for the tap isn't a necessity, just convenience. You could just directly tap the correct winding by soldering on a wire, but that's typically more difficult than creating a little loop at the correct location. Likewise, winding clockwise is a matter of preference.

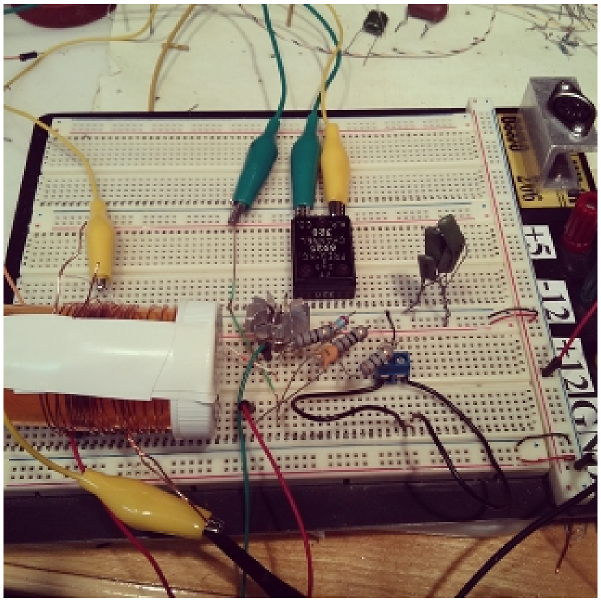
To create L2, just wind the correct number of turns in the same clockwise direction on top of L1, and sand off each edge.

One last part I haven't mentioned is the key. This is where you would attach your morse code key. If you just want to test your circuit to see if it generates a carrier wave, use a wire. I designed mine to have a jumper that I can insert a wire to close the circuit, or add a key.

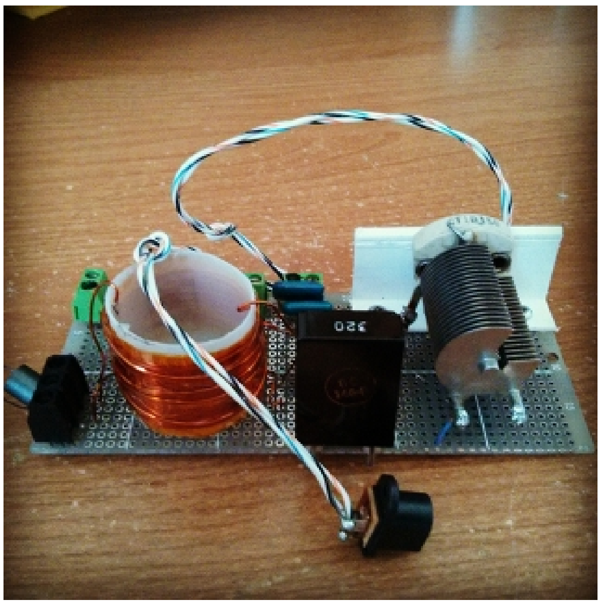
For the antenna, I suggest testing with a 50 ohm resistor or a dummy load. Remember, it's not legal to use such a transmitter on the air unless you are a licensed radio amateur. If you don't have a ham radio license, testing with a dummy load or a 50 ohm resistor should be completely legal since the signal won't radiate very far. If attaching an antenna, shortwave signals travel far even with low watt circuits like this, so be forewarned.

After you assemble the circuit, apply voltage and flip on the radio to the frequency of your crystal. If everything went well, you should hear a carrier wave! Chances are you will need to tune up the circuit with the variable capacitor, so if you don't hear a carrier wave, slowly turn your variable capacitor until you hear one. If you have an RF watt meter, tune your circuit to the highest watts output. If you have an oscilloscope, tune the circuit to have the most clean sine wave.

Here's a pic of the circuit on the breadboard:



And of the completed design:



I constructed the circuit for 40m, and get almost 3/4 of a watt out of it with a 12v supply! That's pretty decent for such a simple circuit.

Now for the bad; this transmitter has one very unfortunate side effect, harmonics. If you want to really use this circuit on the air, you will need to add a low pass filter.

I will cover creating a low pass filter in my next installment, and later discuss adding an audio modulator to turn it into a shortwave pirate transmitter, if you are into that sort of thing.

Posted: Jul 31, 2013

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Bridge: RLB VHF

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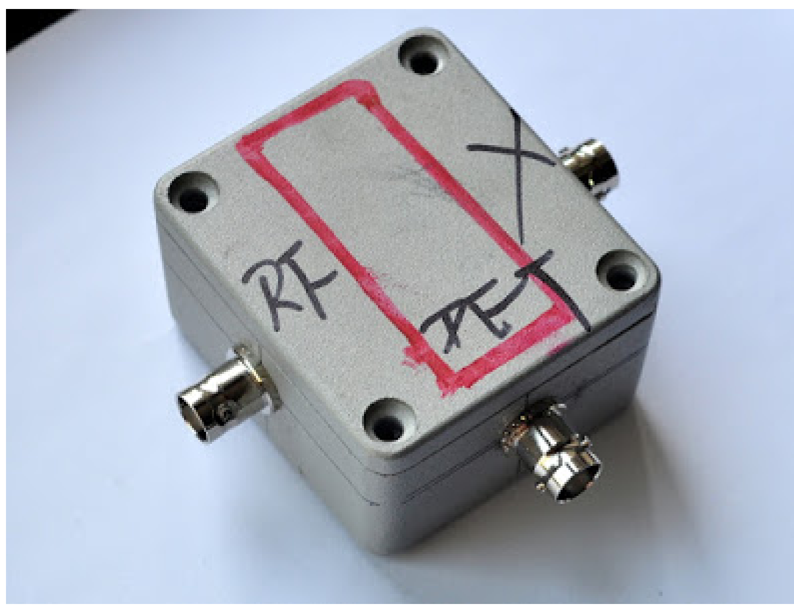
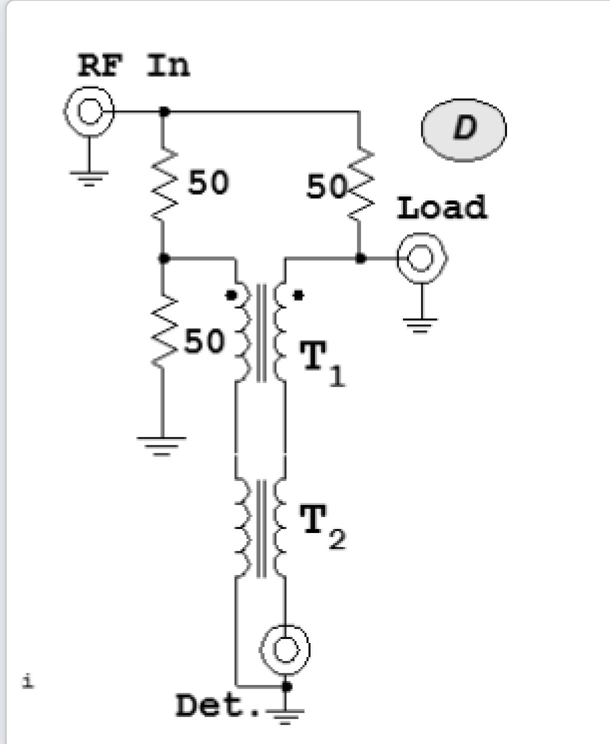
@update whole project , 2013/9/23

Wes Hayward, w7zoi, given a beautiful article **<Toward a Simple Return Loss Bridge>**, which explain and test several implementation about RLB.
I try to built one, and want it work up to 500Mhz, even-through i failed to achieve this goal, but still get a bridge work up to 150Mhz.

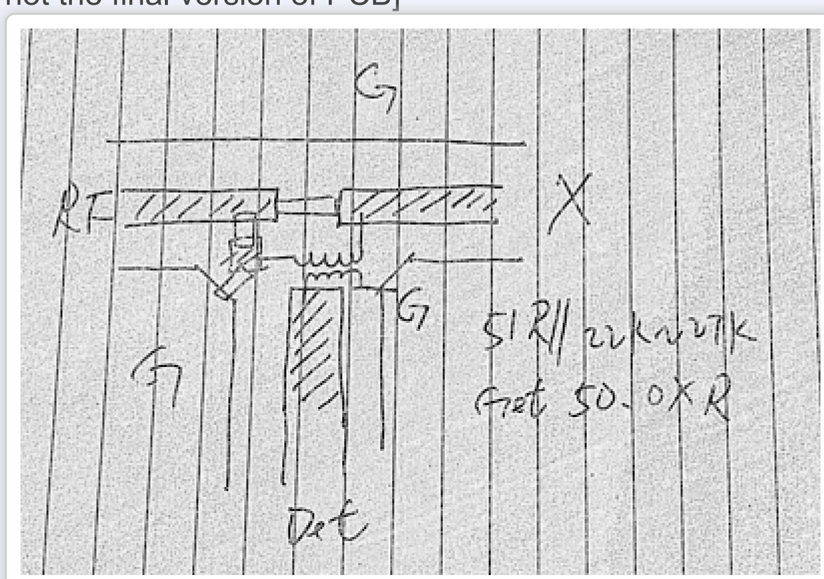


Here is the w7zoi's RLB i was going to build.



T1: BN-73-2402   8T :   6 twister per inch.
T2: FT-37-61 (better UHF than 37-43)
11T: 6 twister per inch.

first version draft design of the PCB (FR-4) [note this is not the final version of PCB]



Here is hint how i get a pecice resistor from 5% 0805 resistor
parallel the 51R resistor with another 3.3k to 4.7k 0805 chip resistor, we got a good resistor very close to 50R.

Contact me

heyongli@gmail.com

G+

51|| 4.3k
51|| 6.2k
51||3.9k
result : 49.98~50.002 (use at least 4 1/2 half DVM).

And all trace use 2H type 50R Microstrip line.

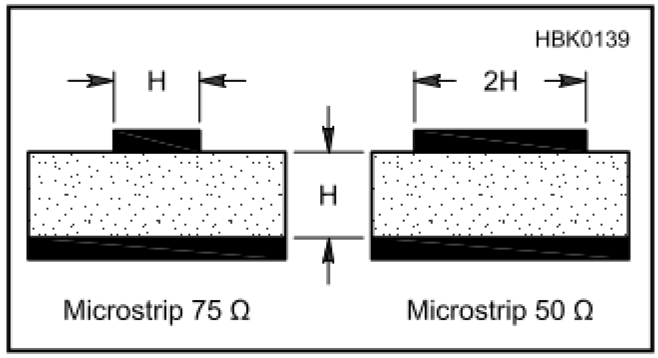


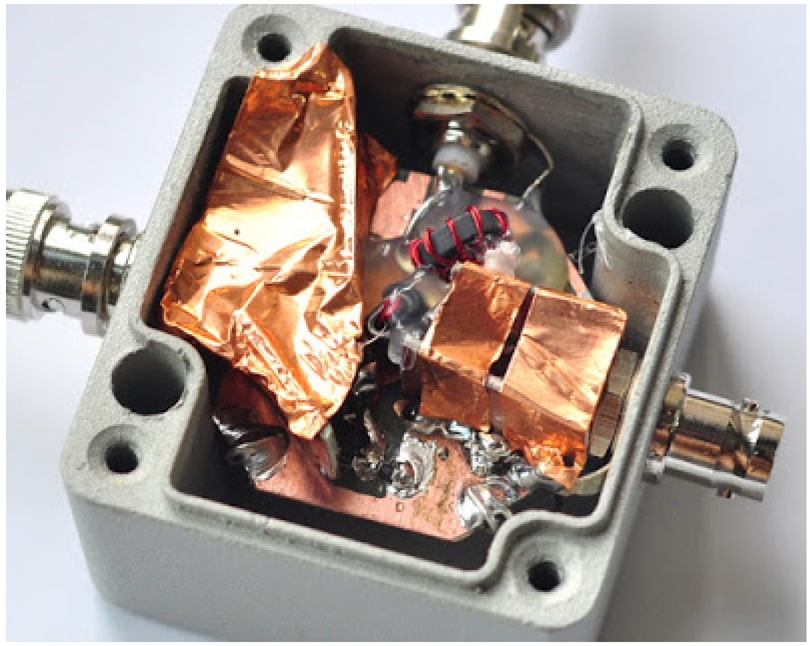
Fig 20.33 — Microstrip transmission lines. The approximate geometries to produce 75 Ω (A) and 50 Ω (B) microstrip lines with FR-4 PC board material are shown. This technique is used at UHF and microwave frequencies.

finished version of the RLB

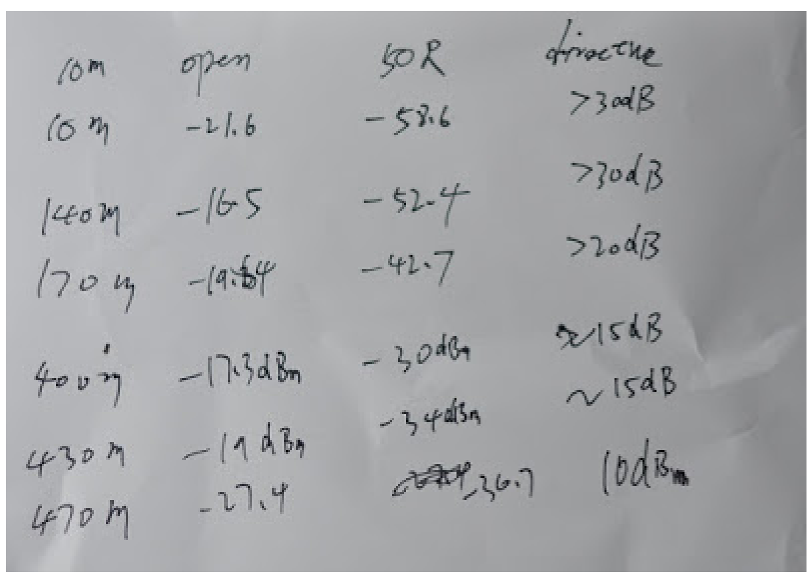
The Big problem is 2 transformer is closed, and T1 is fly over the transmission line, this will be a problem at UHF. but I'm here, i had to finished this.

The final revise and test Result

* i use some copper to isolation the input and output, which improve the directional about few dB.
* use hot glue gun fix the transformer, which improve about 8dB at above 100Mhz, i think the hot glue cut of some signal couple path.



Result is here:



10m	open	50R	directive
10m	-21.6	-58.6	>30dB
140m	-16.5	-52.4	>30dB
170m	-19.64	-42.7	>20dB
400m	-17.3dBm	-30dBm	≈15dB
430m	-19dBm	-34dBm	~15dB
470m	-27.4	-36.7	10dBm

Conclusion

Performance:
1-150Mhz,   directivity > 30dB
170Mhz, directivity> 20dB
400M?, unusable.

why UHF failed:
1.BNC connector is hard to get perfect 50R load, so the testing might not the actual performance of the RLB.
2. T1,T2 is too close and fly over the input.
3. other i don't know yet.

Comments

You do not have permission to add comments.

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Microstrip Ultra-Wideband Filter with Flexible Notch Characteristics

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ABSTRACT

A microstrip ultra-wideband (UWB) filter with unique shape, compactness, simplicity of operation and flexible notch characteristics is introduced. It is based on the fundamental and harmonic characteristics of a 50 Ohm transmission line that is grounded at both ends. The filter possesses design flexibility in the sense that it can operate as a stand-alone UWB component or include simple additional circuitry to create one or two notches within the ultra-wideband frequency range. The basic design principles are highlighted and verified using the results of two commercially available field solver packages. Individual filter structures with single and double notches are validated through measurements of a number of filter prototypes.

Keywords: Microstrip Filters; Microstrip Resonators; Bandstop Filters; Ultra-Wideband Filters

1. Introduction

Ultra-wideband (UWB) applications attract increasing attention, both in industry and academia, due to increasing levels of sophistication and demand for advanced communication systems, e.g. [1]. One of the key issues in the 3.1 - 10.6 GHz range is the interference from wireless local area networks (WLANs) between 5 GHz and 6 GHz. Therefore, general UWB filters, but especially those incorporating notch capabilities, are in demand [2]. Several conventional UWB filter design approaches have been introduced, e.g. [3-5]. The introduction of tunable harmonic stepped-impedance resonators (SIWs) initiated a new generation of UWB filter designs, e.g. [6]. The common critical issue in these approaches, however, is their high manufacturing accuracy due to tightly coupled segments, as they are required to perform over the entire bandwidth [7,8]. Other designs focus on the utilization of defected-ground planes to enhance UWB band-stop specifications, e.g. [9], or SIWs with short-circuit stubs for dual-band applications [10].

In order to eliminate interference from other services within the UWB band, a UWB filter must provide additional narrowband rejection capability in the passband. One solution to meet this specification is to utilize conventional open-ended quarter-wavelength transmission lines, which reject signals at that specific frequency [11,12]. A number of additional options, including those involving technologies other than microstrip, are discussed in [2].

This paper introduces a compact UWB microstrip filter, which is not only easy to prototype but also provides design flexibility for single and double notching within the UWB passband. The stand-alone UWB filter follows from work recently presented in [13,14] where also tuning capability with respect to a certain notch configuration is demonstrated. The current paper presents new possibilities of creating single or double notches while maintaining the circuit dimensions of the original UWB filter. Several prototype measurements validate the design approach and the additional circuitry for notch creation.

2. Design Guidelines

2.1. Stand-Alone UWB Filter

Figure 1(a) shows the layout of a triple-resonator microstrip filter whose operation is based on the resonance characteristic of a 50 Ohm transmission line which is grounded by via holes at both ends [13]. Its basic operation is explained as follows (**Figure 1(b)**). Length L is chosen to be a half wavelength at center frequency of $f_0 \approx$ 6 GHz. Lengths L_1 are quarter-wavelengths sections at the same frequency so that the entire length forms a full-wavelength via-grounded transmission line. The impedance of the main transmission line L and input/output sections is 50 Ohm. Source (input) and load (output) are tapped to the resonator at points where all three modes

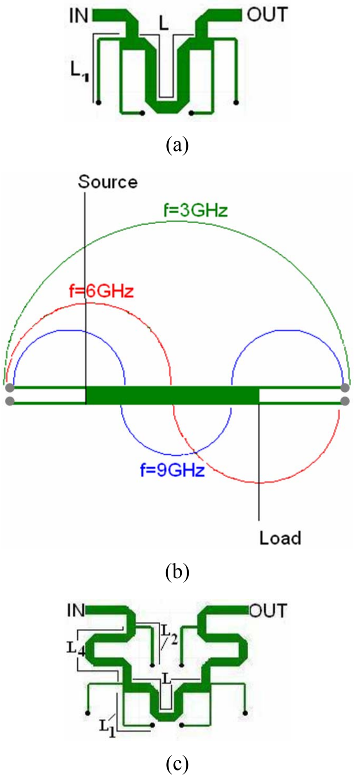


Figure 1. (a) Layout of triple-resonator microstrip filter; (b) Explanation of fundamental resonance and first and second harmonics at around 3 GHz, 6 GHz and 9 GHz, respectively; (c) Layout for bandwidth enhancement.

are excited (**Figure 1(b)**). The quarter-wavelength sections L_1 are realized as two parallel segments of 100 Ohms each. This is not a necessary condition for the operation of the triple-mode resonator but has shown some minor benefit in the design process as it provides slightly increased flexibility. Ideally, these segments have an impedance of 100 Ohms and support a compact size through structural folding. For ease of fabrication, though, their minimum width might be limited. Therefore, their minimum width is set to, e.g., 100 µm, thus resulting in slightly lower impedance. Alternatively and depending on the substrate used, impedances are limited to 100-Ohm lines if they lead to line width ≤ 100 µm.

In addition to the filter of **Figure 1(a)**, **Figure 1(c)** depicts sections L_2 and 50 Ohm lines L_4 in order to increase the bandwidth of the UWB filter. The sections of length L_4 operate as quarter-wavelength impedance inverters at 3 GHz and as half-wavelength resonators at 6 GHz. Lengths L_2 are a quarter-wavelength long at around 6 GHz. Their impedance level and/or width are selected in the same way as sections L_1. Using RT/Duroid 6010 substrate with ε_r = 10.2, substrate height h = 635 µm and metallization thickness t = 35 µm, the overall dimensions of the filter structure in **Figure 1(c)** are 11 mm × 8 mm.

Figure 2(a) shows the responses of the filter in **Figure 1(c)** obtained with Ansoft Designer and the High-Frequency Stucture Solver (HFSS). (Ansoft Designer and HFSS are two different commercially available field solvers, the first based on the method of moments, the latter on the finite element technique. They are used together in this paper for the purpose of result validation as a single numerical technique, depending on its specific implementation, is often not an indication of a reliable design.) Good agreement is obtained for the passband and most of the stopband. According to Ansoft Designer, the 20dB band-stop region extends from 11 GHz to 14.15 GHz. The transmission zero at 11.3 GHz is due to the fact that the input/output placements along the grounded transmission-line resonator create an out-of-phase feeding scenario similar to that discussed in [15]. (Note that his transmission zero is inherent in the design and appears in all filter responses shown in this paper.) The 3dB bandwidth extends from 3 GHz to 10.4 GHz and covers almost the entire UWB frequency range. **Figure 2(b)** shows the group delay response of the filter in **Figure 1(c)**. In the passband, it is derived from the computed or measured transmission phase φ_{21} as

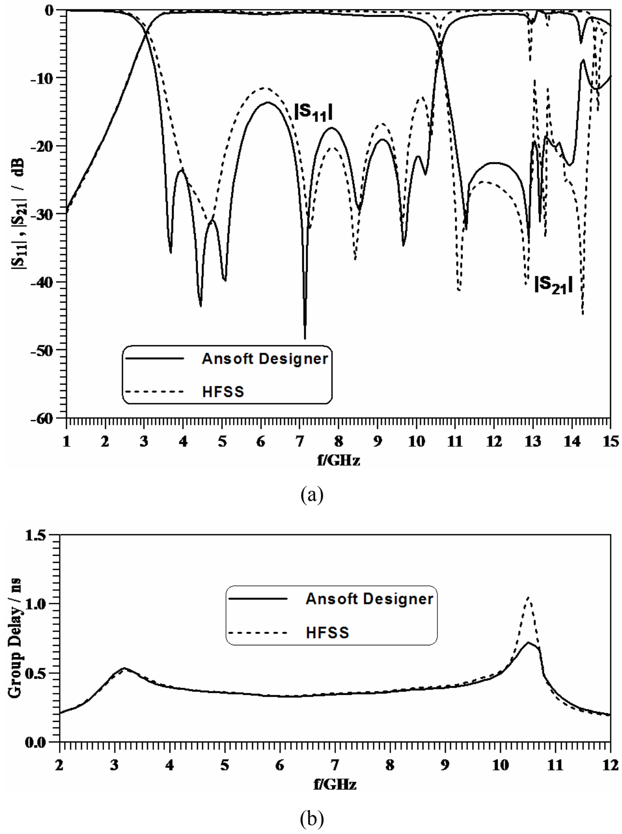


Figure 2. Scattering parameters (a) and group delay (b) of the UWB microstrip filter in Figure 1(c); performance comparison between Ansoft Designer and HFSS.

$$\tau = -\partial\varphi_{21}/\partial\omega \tag{1}$$

In the stopband or at transmission zeros, the output signal is diminished due to high attenuation, and thus the group delay is extracted using the phase φ_{11} of the reflection coefficient and the properties of lossless symmetrical two-port devices.

$$\varphi_{11} = \varphi_{21} \pm \pi/2 \tag{2}$$

Since the group delay is meaningful only at passband frequencies, **Figure 2(b)** (and following group delay plots) focuses mainly on the ultra-wide passband. For the circuit in **Figure 1(c)**, good agreement in and close to the passband is observed in **Figure 2(b)**. The group delay variation is less than 200 ps as confirmed by Ansoft Designer and HFSS and is thus better than or comparable with many UWB filters presented in the recent literature.

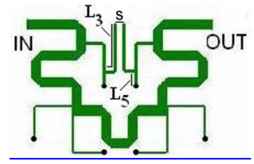
2.2. UWB Filter with Notch Capability Specifications

Up to this point, we were concerned with the filter as a stand-alone UWB component. Now the creation of a notch in the frequency response is demonstrated. This is achieved by adding open-ended coupled-line sections L_3 and tapping them off lines L_2 at a distance L_5. A comparison between **Figures 1(c)** and **3(a)** illustrates the concept. The open and shorted stubs formed by lengths L_2 in **Figure 1(c)** and L_3, L_5 in **Figure 3(a)** have band-stop characteristic and thus create the notch in the frequency response. Note that the notch is absent in **Figure 2(a)** because lines L_2 in **Figure 1(c)** are too short for the UWB frequency range. For design purposes, length L_3 in **Figure 3(a)** is determined as

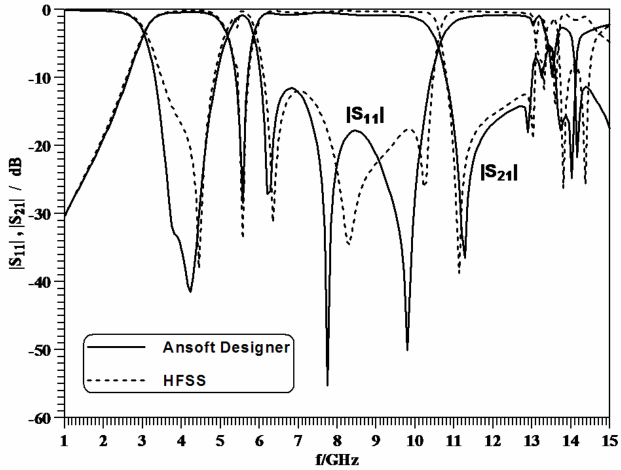
$$L_3 = (\lambda'/4) - L_5 \tag{3}$$

where λ' is the guided wavelength at the desired notch frequency. **Figure 3(b)** and **(c)** show the scattering and group delay performances, respectively, for this filter. The notched 3 dB bandwidth in **Figure 3(b)** is 800 MHz, covering the frequency range from 5.2 GHz to 6 GHz, and the maximum attenuation is 30 dB. Other than that, the performance of the filter in **Figure 3(b)** is similar to that in **Figure 2(b)**. The group delay performance in **Figure 3(c)** shows variations of less than 100 ps and 200 ps for the first and second passbands, respectively.

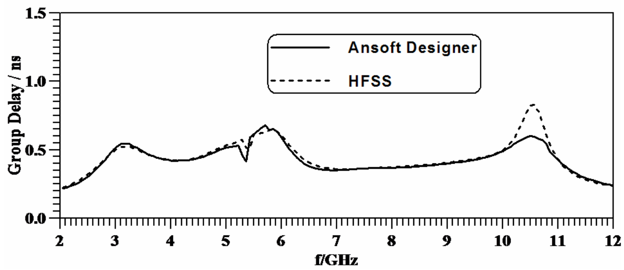
Tuning of the notch is facilitated by varying lengths L_3, L_5 and adjusting the spacing "s" between the coupled lines. The 3 dB bandwidth of the notch is adjusted mostly by L_5, but also slightly by L_3, which then changes in the opposite direction according to Equation (3). In addition, the reflection coefficients within the two passbands (initial UWB filter response now separated by the notch) are slightly adjusted by the gap "s" between the open-ended coupled segments of length L_3. This has been initially demonstrated in a parametric study presented in [14].



(a)



(b)

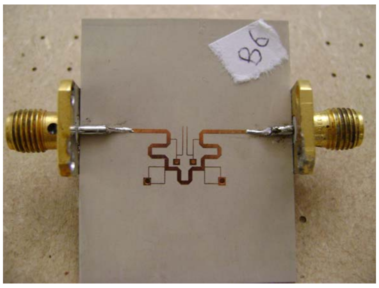


(c)

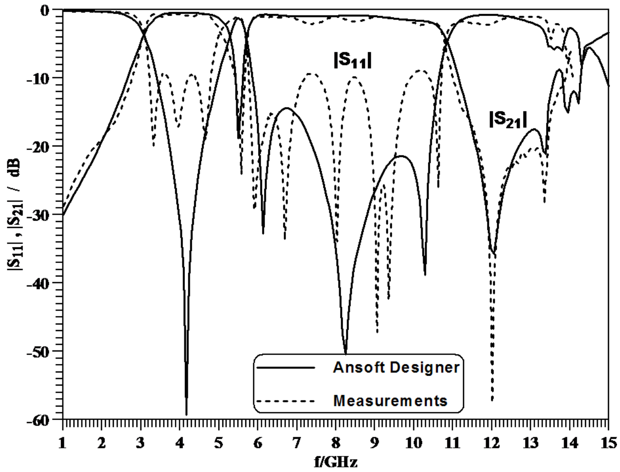
Figure 3. Layout (a), scattering parameters (b) and group delay (c) of the UWB microstrip filter with notch characteristic; performance comparison between Ansoft Designer and HFSS.

3. Results

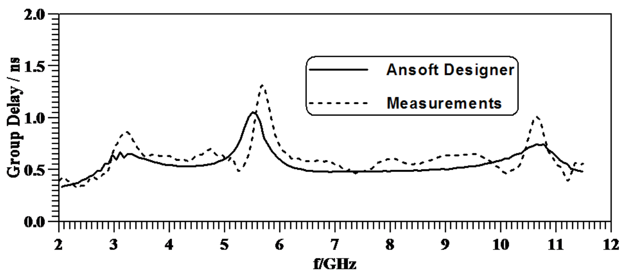
This section shows some of the results obtained with selected prototypes. About 16 different designs were implemented on a single RT/Duroid 6010 substrate with ε_r = 10.2, substrate height h = 635 μm and metallization thickness t = 35 μm. They were cut to individual filter units, and coaxial connectors were soldered to input and output ports as a test fixture was not available. One of the problems in this prototyping approach is the fact that the input and output coaxial adapters, as shown in **Figure 4 (a)**, are located very close to the actual filter circuit. They are responsible for the high level of reflection seen in the passbands in **Figure 4(b)** and the somewhat wavy group delay response in **Figure 4(c)**. (Similar behavior is ob-



(a)



(b)

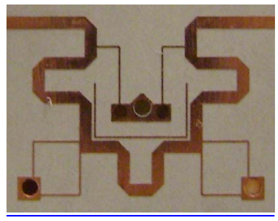


(c)

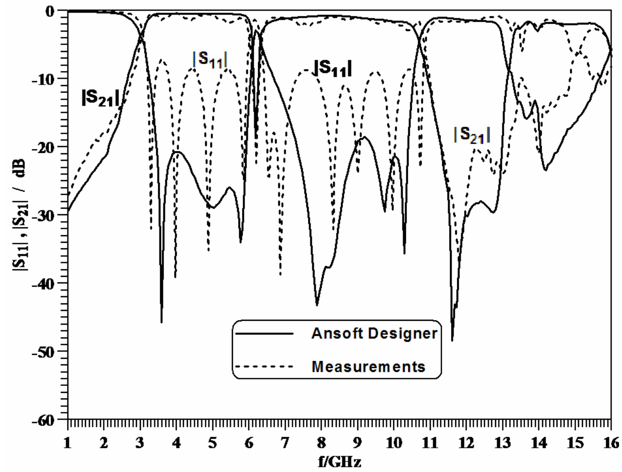
Figure 4. Photograph (a), measured S parameters (b) and group delay (c) of a UWB microstrip filter with notch characteristic; performance comparison with Ansoft Designer.

served for all following measurements in this section.) Other than that, the agreement between computation and measurements is very good. The measured passband return loss is about 10 dB, and the notch frequency at 5.55 GHz and the transmission zero at 12 GHz are well represented in the experiment.

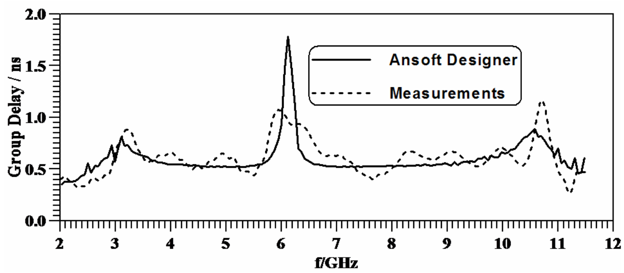
According to **Figure 3(a)** and the discussion in the previous section, a notch in the UWB filter performance can be created by employing open and shorted stubs between the input and output paths and designing their lengths and position for the notch frequency. However, the position and character of the stubs is not limited to that shown in **Figures 3(a)** and **4(a)**. For instance, **Figure 5(a)** shows coupling directly across the original



(a)



(b)

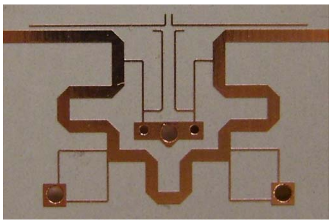


(c)

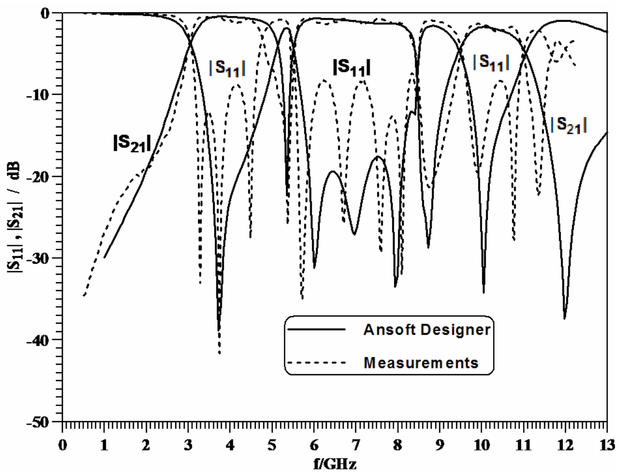
Figure 5. Photograph (a), measured S parameters (b) and group delay (c) of a UWB microstrip filter with notch characteristic using an alternative coupling scheme; performance comparison with Ansoft Designer.

triple resonator (**Figure 1(a)**) whereas the upper filter part is similar to **Figure 1(c)** with the exception that the two vias at the end of lengths L_3 are realized by a combination of vias. The length of the coupling path is a half-wavelength at the notch frequency. The measurements in **Figures 5(b)** and **(c)** show similar characteristics as the previous ones. The measured return loss is about 8 dB, and the notch at 6.2 GHz and the overall transmission characteristics are well reproduced in the experimental data.

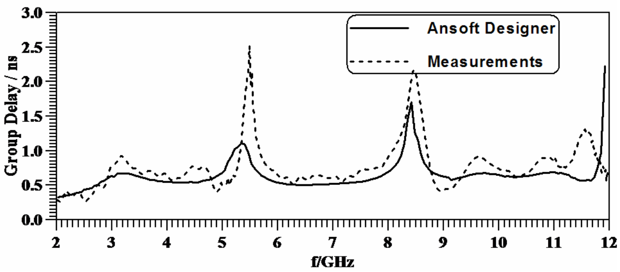
Double notches in the UWB filter response can be created by using the circuit in **Figure 4(a)** and adding another half-wave resonator between input and output. This is demonstrated in **Figure 6(a)**. The former thus produces the notch at 5.45 GHz while the latter adds that



(a)

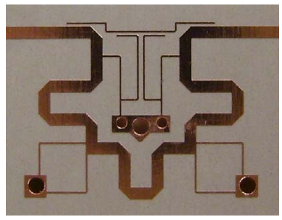


(b)

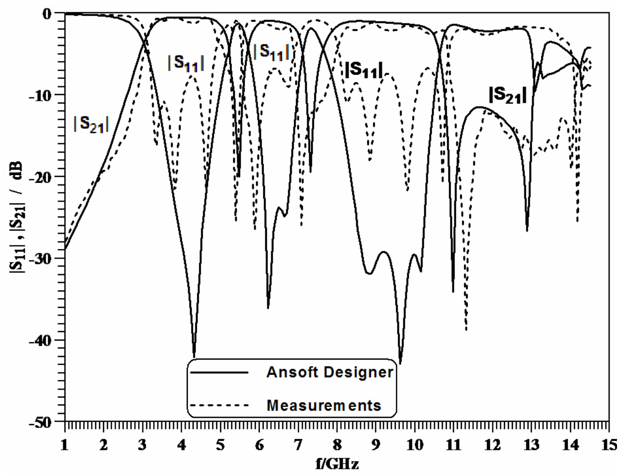


(c)

Figure 6. Photograph (a), measured S parameters (b) and group delay (c) of a UWB microstrip filter with double notch characteristic; performance comparison with Ansoft Designer.



(a)



(b)

Figure 7. Photograph (a), measured S parameters (b) of a UWB microstrip filter with double notch characteristic and alternative coupling scheme; performance comparison with Ansoft Designer.

at 8.75 GHz. Although the upper notch band is wider relative to the notch center, the UWB response is clearly divided into three separate passbands as indicated by "$|S_{11}|$" in **Figure 6(b)**, and the measured filter transmission characteristic is in good agreement with predictions. The group delay performance in **Figure 6(c)** also reflects the triple-band filter characteristic.

Similar to the single-notch designs, the coupling schemes for the double notch can now be changed. Note that the dimensions of the basic 50 Ohm resonator line as well as those of the input/output lines are the same in all prototypes presented in this paper.

A variant of the circuit in **Figure 6(a)** is shown in **Figure 7(a)**. Comparing the responses of **Figures 6(b)** and **7(b)**, it is seen that the same scheme is used to produce the lower notch at 5.45 GHz (also c.f. **Figure 4**). The scheme for the upper one is altered and produces a notch designed for 7.3 GHz (**Figure 7(b)**). However, note that there is an uninterrupted line between the input and output coupling sections and that, compared to **Figure 6(a)**, the coupling of the lower-notch lines to the upper one is stronger in **Figure 7(a)**. It is believed that this is the reason for this configuration being more sensitive to tolerances. This fact explains the shift from 7.3 GHz in the computation to 7.05 GHz in the experiment (**Figure 7(b)**). Other than that, the notches and overall transmission characteristic are well represented and, considering the reflection effect between the coaxial adapters (as mentioned earlier), the agreement between computation and experiment is generally good.

4. Conclusion

A microstrip ultra-wideband filter is introduced. Due to its unique shape and compactness, it offers possibilities for single and double notch operation. The filter's centerpiece is a 50 Ohm transmission line, grounded at both ends, plus additional 50 Ohm and (ideally) 100 Ohm line sections. Open and shorted lines between the input and output halves of the filter facilitate a narrow notch band.

Additional coupled half-wave resonators generate additional notches at different frequencies. The applications of the circuits are two-fold: They can be used for interference cancelation of other services in the UWB frequency range, or they can operate as dual-or triple-band filters within the 3 - 10 GHz regime. Principle design guidelines determine the initial UWB filter and notch dimensions. Fine optimization with a field solver such as Ansoft Designer or HFSS is encouraged. Several prototypes are presented whose measurements, aside from the inappropriate prototyping, validate the basic filter design and the creation of notches in the frequency response.

5. Acknowledgements

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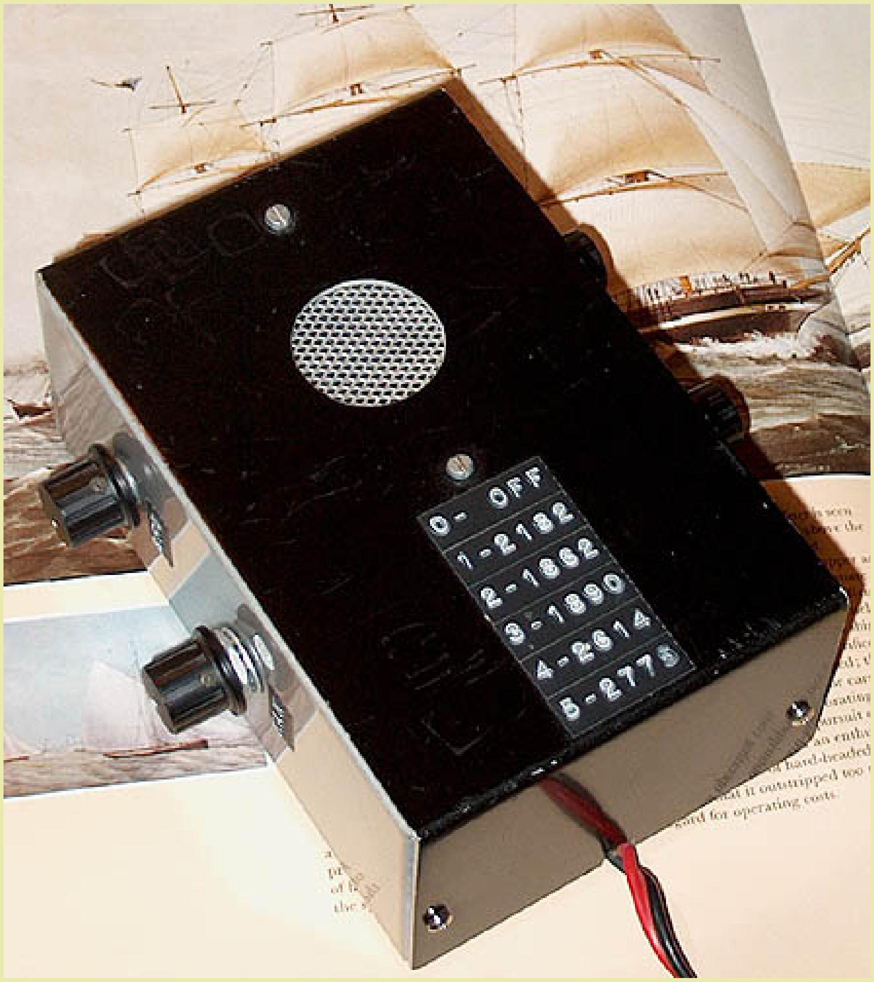
MARITIME RECEIVER

(1985)

KLIK HIER VOOR DE NEDERLANDSE VERSIE



The maritime receiver for the reception of weather forecasts.

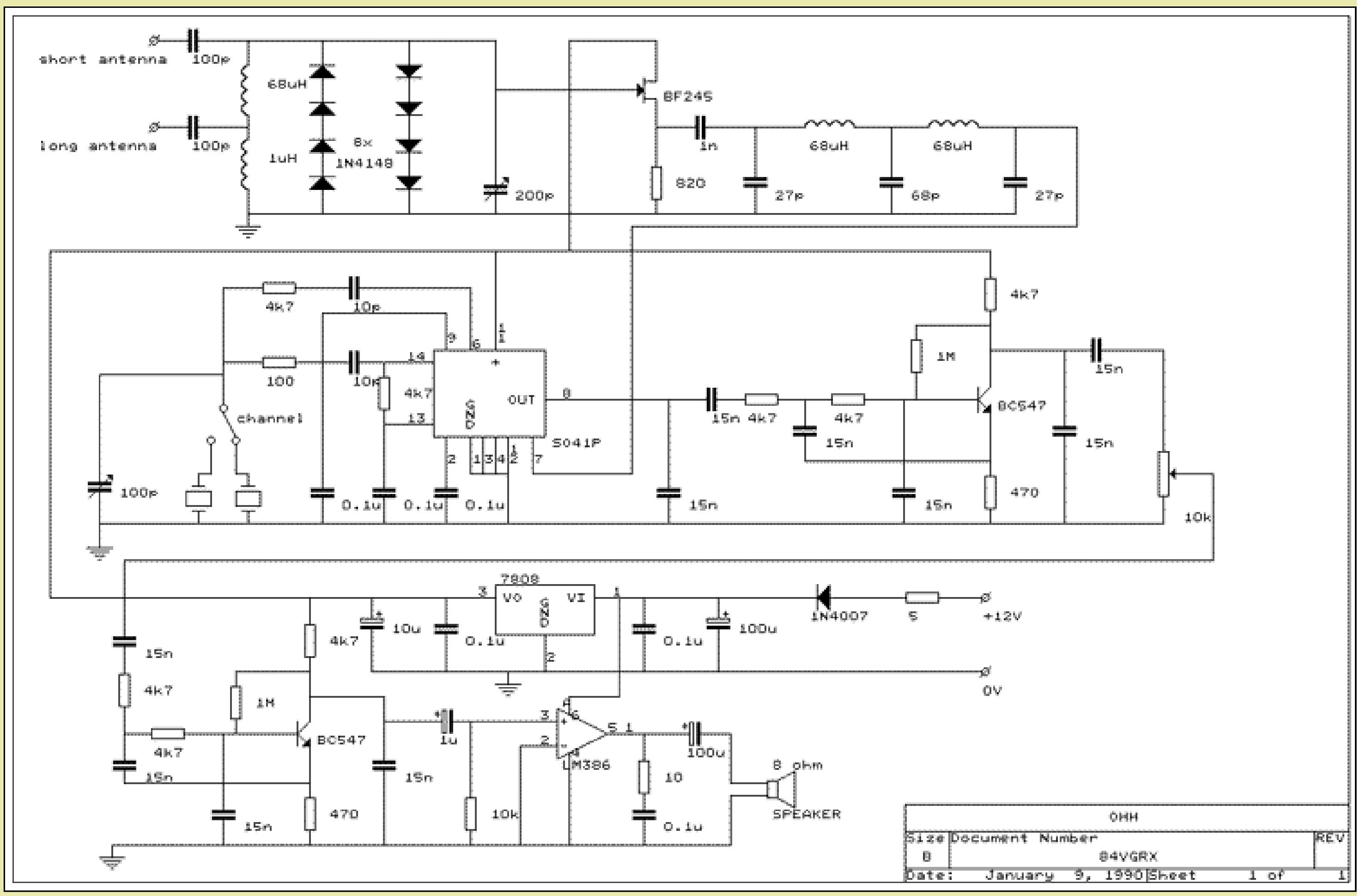
The maritime receiver for reception of coast stations.
Reception of weather forecast and wind warnings transmitted by coast stations is very important when sailing on sea. I wanted a small and simple receiver that could be easily tuned to the desired frequency and with good stability for the Single Side Band signals. There were two coast stations in my sailing area, so only a few frequencies were needed.
This simple receiver with 5 crystals can easily be tuned to the desired frequency. And because of the crystals, frequency stability for SSB reception is very good. Even 18 years after its last use and without the use of the fine tuning, it was exactly on the frequency of 2182 kHz for SSB reception when switched on for fun.

Frequencies and coast stations		
Switch position	Frequency (kHz)	Station
0	None	Off
1	2182	International calling and distress MF frequency

2	1862	Scheveningen radio north
3	1890	Scheveningen radio west
4	2614	Norddeich radio
5	2775	Norddeich radio

Explanation
This receiver is a simple direct conversion receiver. The local oscillator works on the reception frequency. There is no IF, the output of the mixer is the LF signal. A disadvantage is that both sidebands are received, but in practice this was never a problem. There were never signals on the other side band when receiving SSB signals of a coast station.

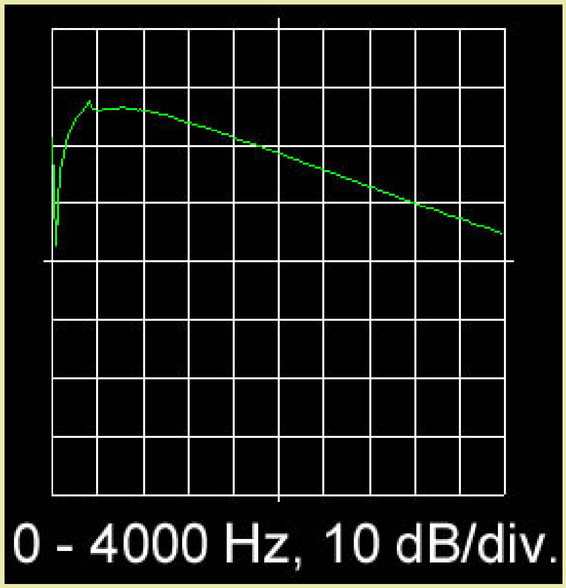
RF amplifier
At the input, an LC circuit is tuned to the reception frequency with the variable mica capacitor. The receiver is tuned to the maximum noise level. The diodes do protect the FET againsg high peak voltages. The purpose of the selective input filter is to suppress all kinds of strong signals on other frequencies than the reception frequency. This LC circuit is followed by an amplifier with a FET BF245. This FET is not a voltage amplifier but a current amplifier or an impedance converter: the input has a high impedance, the output has a low impedance.
After the FET, you can find a low pass filter with a cut off frequency of 4 MHz. The receiver is also sensitive for signals on 2x and 3x the reception frequency. This filter suppresses the strong signals above 4 MHz on these frequencies.



Circuit diagram
[big diagram](http://www.qsl.net/pa2ohh/85marrx.htm)

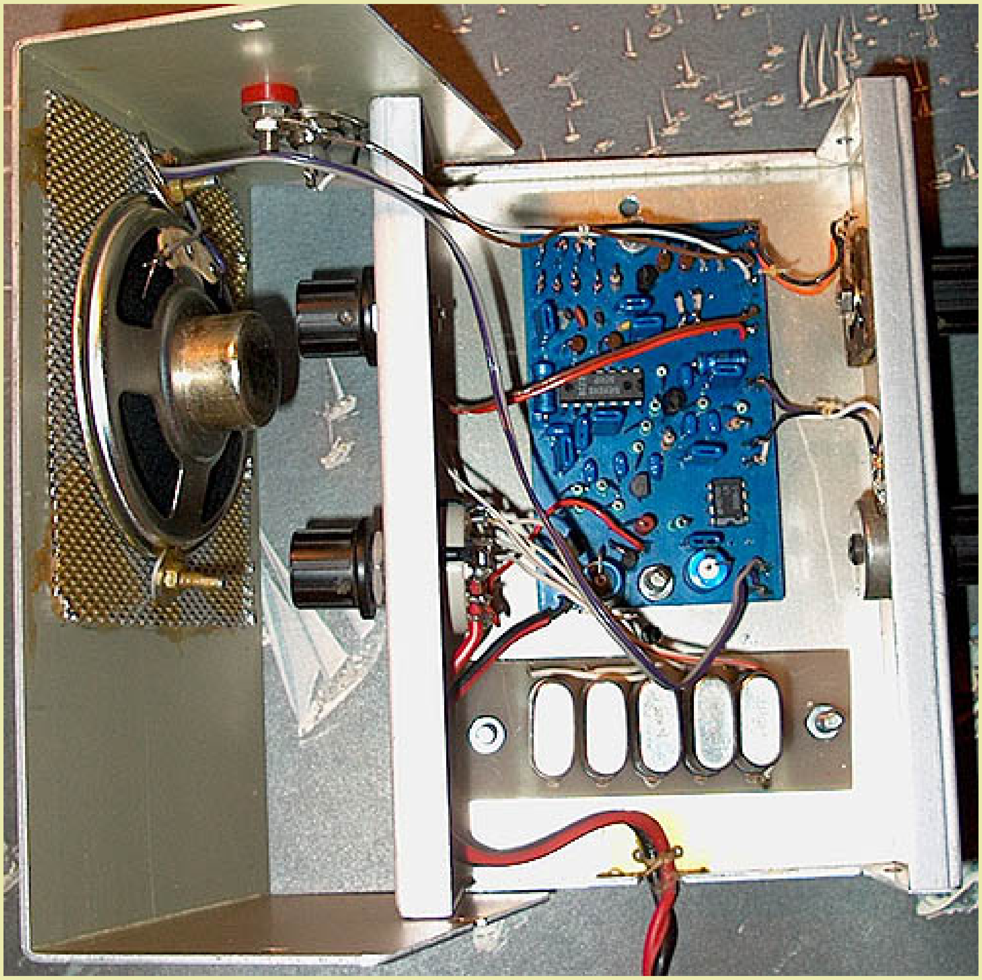
Mixer and Local oscillator
The IC SO41P contains the mixer and also the local oscillator. Because of the expensive crystals, it was not a cheap receiver. In the diagram, only 2 crystals are shown, but the receiver has 5 crystals and a 2x6 position switch. The 6th position of the second section is the OFF position of the receiver. The crystal frequency is equal to the frequency of the coast station. Fine tuning for SSB reception can be done by a second variable mica capacitor. The receiver was supplied from a 12V accu that also was used for the depth sounder and for the lights.

LF filters and amplifier
The LF signal at the output of the mixer is filtered and amplified by two stages with a BC547 transistor. The volume control can be found between the two stages. A simple final LF amplifier with a LM386 drives a small loudspeaker. An 7808 IC stabilizes the 8V for the whole circuit, except the final LF amplifier. The audio frequency characteristic does not look so very good. But it compensates the frequency characteristic of the small internal loudspeaker, that is not so sensitive for lower frequencies.



Audio frequency characteristic.

Results
This simple receiver did an excellent job. When sailing on a moving boat over the waves, tuning of a receiver for the reception of SSB signals is always difficult. But not with this receiver! In only a few seconds it was tuned to the coast stations and ready. Reception of the weather forecasts and navigational warnings was always very good. Only the short antenna connection was used with a wire antenna of approximately 1 meter in a polyester boat.



Inside view


A

(Onno 1986)
The small sailingboat the receiver was designed for.

[BACK TO INDEX PA2OHH]

DIY Audio Home

815 Class AB2 amp

Mr. and Mrs. Potatohead live!

I have the stereo pair of 815 amps assembled. Testing is ongoing... on the 8 ohm taps, I get over 50 watts out, and still low THD at 1 watt (~0.02-0.04%).

I have not yet listened to them.

Here's what it looked like on the breadboard:

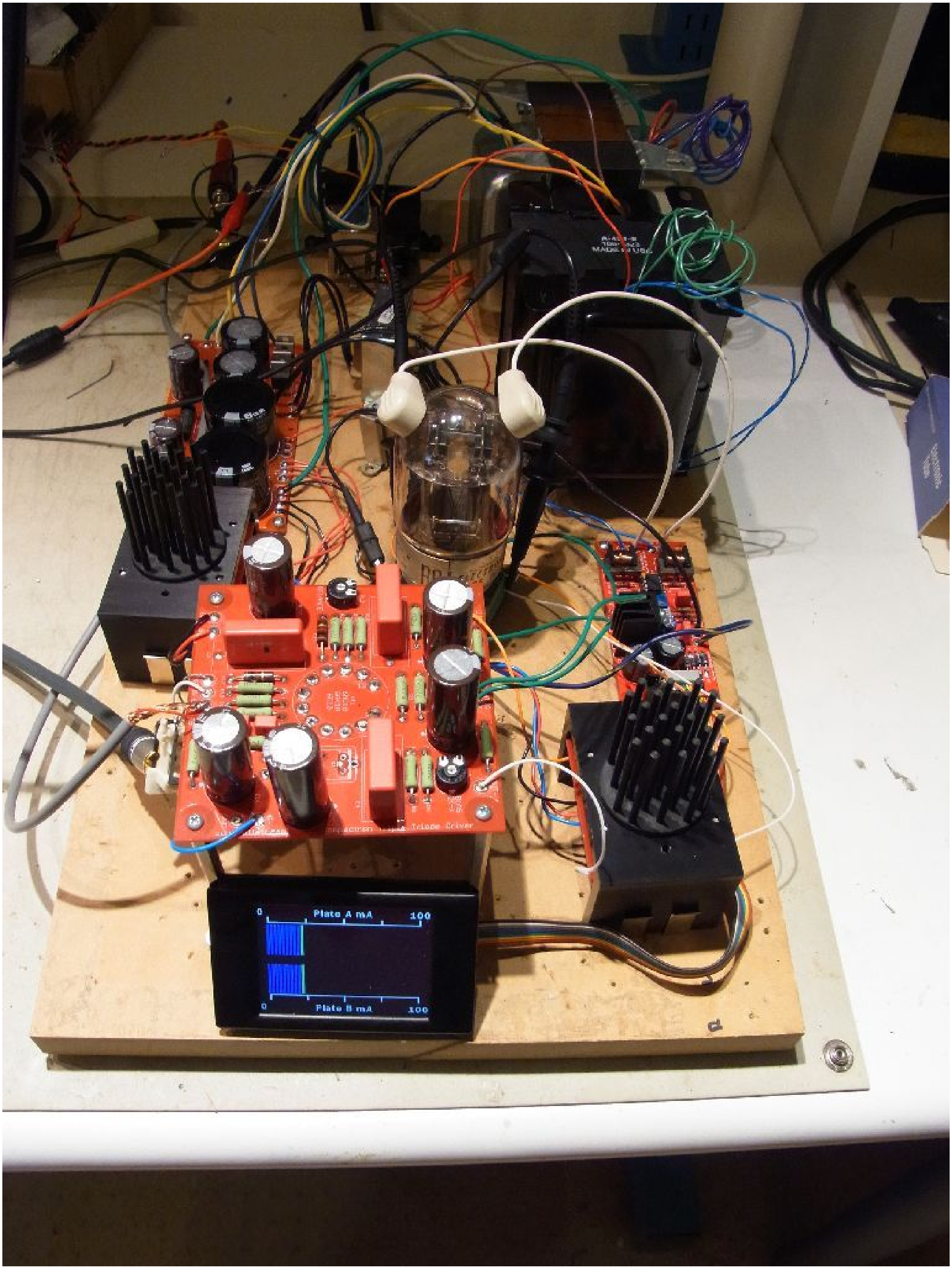


Plate A mA
0
100
Plate B mA
0
100

The 815 is a bit of an ugly duckling. It is a pair of 2E26 beam tubes in one glass envelope, designed for RF transmitting use.

The 815 and 2E26 have never been very popular as audio amps. They have a low plate dissipation rating, a low maximum screen grid voltage rating, and are not very linear when operated in class A or AB1 (mostly due to those restrictions).

However, if you operate them close to the published ratings in class AB2 (where you drive the grids positive), the performance is pretty impressive.

I get 50W out from a B+ voltage of 475V, and 0.02% THD at 1 watt. Using a Dynaclone A431S output transformer, the frequency response is within +/-0.3dB 20Hz-20kHz, with -3dB at 75kHz or so. More measurements, FFT, IMD, etc. coming soon.

The driver PCB uses a 6AC10 triple triode compactron, so the whole amp uses only two tubes (granted, multi-section tubes). It uses MOSFET source followers to drive the grids of the 815 positive (that's the black heatsink at lower right), and a "Maida" regulator to generate a 125V screen voltage (black heatsink at the left). A power supply at the left rear generates 475V, 235V, and -95V from a ClassicTone Marshall amp power transformer (40-18053).

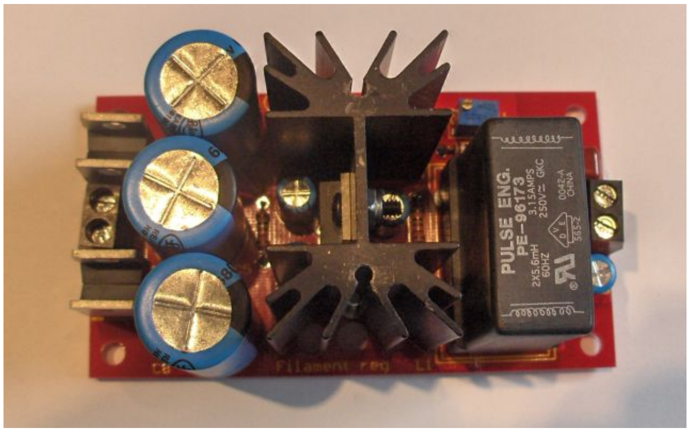
Plate current for each plate is measured using an isolated current sensor and a PanelPilot programmable LCB panel meter. Since the cathodes are internally connected, you cannot sense the current there, and I wanted to be able to separately adjust the bias on each half of the 815.

All these PCBs are available on eBay.

[DIY Audio Home](#)

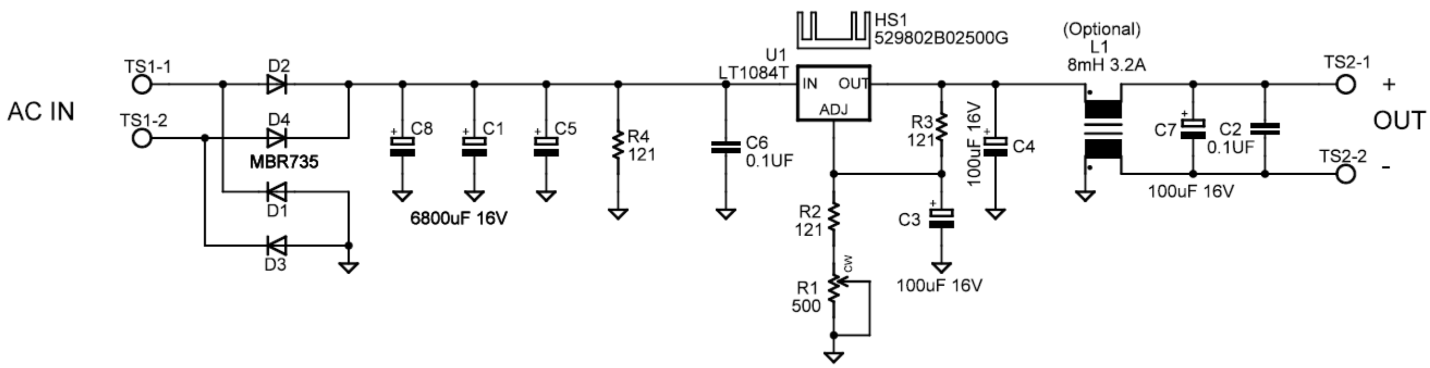
Regulated DC power supply or filament supply

I designed and built a simple DC regulated power supply to drive the 300B filaments in the "Unnecessarily Complex 300B Amp" some time ago. Since then I have had a number of requests to buy PCBs for this circuit. I finally have gotten around to optimizing the design and now have some boards available. You can find the PCBs on eBay by clicking here.



Although I designed this mostly to use as a DC supply for tube filaments or heaters, it is a general-purpose DC supply that has many applications. Basically just add a transformer to get a regulated DC voltage in the 1.25V to ~25V range, at up to 5 amps. You can connect two modules to get a bipolar supply (for opamps, for example) - see below.

Here is the schematic (click on the image for a full PDF schematic):

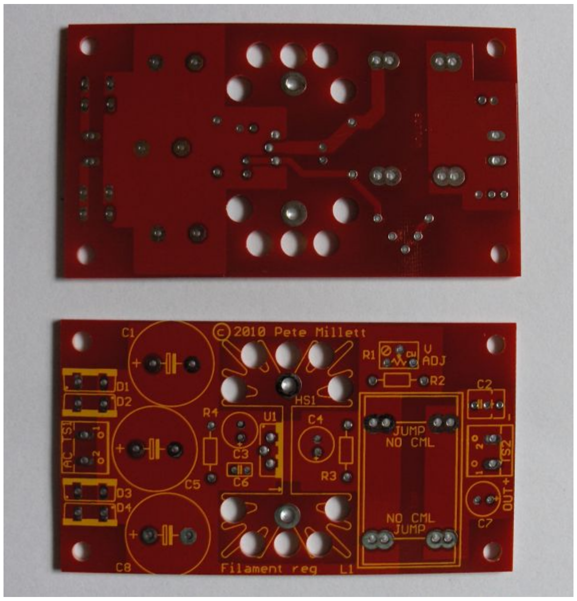


Just a simple rectifier/filter, LT1084 or LT1085 (or similar) voltage regulator IC, and a common-mode choke like the ones used on switching power supplies. The common-mode choke is optional - you can install two jumpers if you don't want it. It is intended to help reject common-mode noise that might capacitively couple across the power transformer from primary to secondary. It can also help filter rectifier recovery noise. Note that due to resistance in the common mode choke you need to adjust the voltage under load... you lose a couple tenths of a volt across the CML.

Note that if you are using this at a higher voltage like 10 or 12V, you will need to make R1, R2 and R4 higher resistance or they will dissipate more than 1/4 watt.

I designed the PCB to be the same form factor as the Tent Labs filament supply, which is a more complex voltage-controlled current source (which works very well, by the way). That way I could switch between the two without any major modifications.

Here's what the PCB looks like (click for a full-size image):



You can download a BOM either in [PDF](#) or [XLS](#) format. I also have a Mouser project BOM that you can access via [this link](#). Note that the BOM has a 1uF cap on the output (C2) whereas the schematic has 0.1uF. You can use either - 1uF is arguably better.

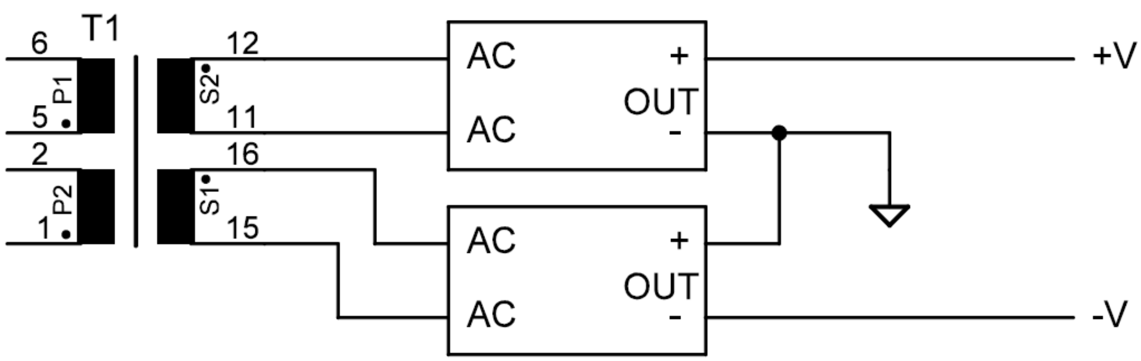
Total cost for the parts is just over $20 each, plus the PCB. I'm selling them for $30 per pair on [eBay](#).

Output voltage and dual supply connection

The output voltage is set by the resistor divider (R1, R2, and R3) connected to the LT108x feedback pin, which is regulated at 1.25V below the output. For details, refer to the [LT108x datasheet](#).

With the values shown in the schematic and BOM, the output can be adjusted from 2.5V up to 7.6V by adjusting the trimpot R1. If you wanted a range of 10V to 20V (for opamp supplies, for example), you could make R2 820 ohms and the trimpot R1 1k. You would also want to increase the bleeder resistor R4 to something bigger, like 1k.

If you have a transformer with dual secondaries, you can use two of these supplies to make a bipolar (+/-) supply. You would connect two modules as shown below:



Input voltage and current

To maintain it's regulated output voltage, the DC voltage input to the regulator IC must remain slightly above the desired regulated output voltage (the minimum difference between input and output is referred to as "dropout voltage"). For the LT108x series, a 1.5V minimum difference is recommended. So, for a 5.0V regulated output, you should have 6.5V minimum at the input of the regulator (or output of the filter).

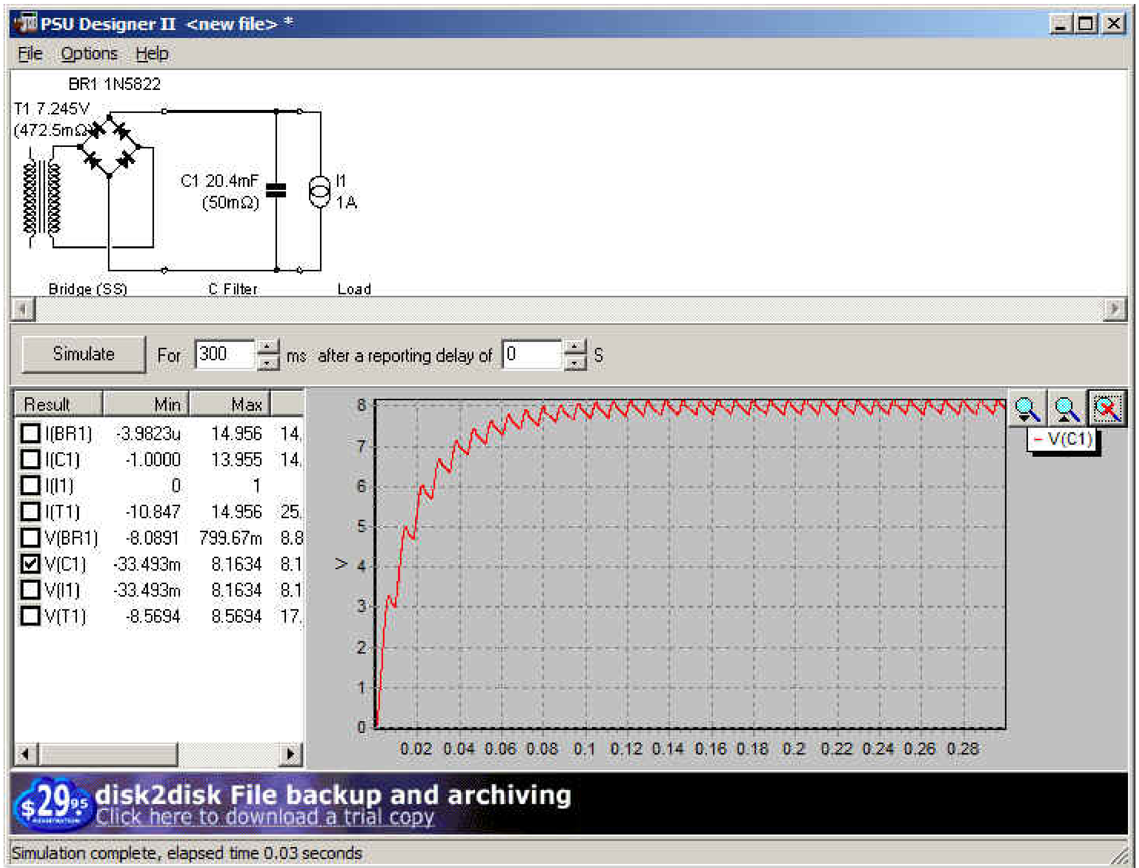
To determine what voltage the transformer secondary needs to be for proper operation, you need to consider this minimum voltage, the ripple voltage, and the voltage drop across the diodes. The peak DC voltage (top of the ripple waveform) is approximately [1.4 * (RMS transformer voltage)] - 1.0V, where the 1.0V is the drop across two diodes. The ripple voltage depends on the current output of the supply and the power supply capacitance (3 * 6800uF in the BOM, or 20.4mF). The ripple voltage is approximately I/(2*f*C), where f is 60 (60Hz mains) or 50 (50Hz mains). As an example, for a 1A load current and 60Hz mains, the ripple voltage would be about 0.4V.

If you add all this up: 6.5V (minimum input to regulator) + 1V (diode drop) + 0.4V (ripple) you get 7.9V. Now you multiply this by 0.707 to get the RMS voltage, which gives you 5.58V RMS. That is the *minimum* voltage you need for the transformer secondary. To keep the amount of

power dissipated in the regulator as low as possible, you should use the next higher voltage available. In this case that would probably be a 6V transformer.

The RMS current rating of the transformer should be a minimum of 1.8x the DC output current. This is a general rule of thumb, and it does depend on the transformer itself. So for the 5V 1A output example above, ideally you'd want a 6.3V 1.8A transformer. Higher current ratings are good (2A would be a good choice here - the higher the current rating the cooler the transformer will run).

Now, if you're lazy like me, it is easier to use Duncanamps PSUD power supply simulator to get an idea about what you need. I entered the parameters for a 6.3V 2A transformer with 15% voltage regulation (typical for a cheap transformer). Here's the result:



The minimum DC voltage (bottom of the ripple) is about 7.75V, which gives you 2.75V of dropout voltage for the regulator.

If you are using this for a filament supply, some guidelines: For a 300B at 5V and 2A, use a 6V (or 6.3V) transformer rated at 4A or more (a 5V transformer *may* work but is pushing the dropout voltage). A 2A3 is good with 5V at 4A. For 6V 1A (like for a preamp), you can use a 6.3V 2A transformer (or winding on a plate transformer).

Power dissipation

Nothing is free. If you have 1A of current flowing and 2.75V drop across the regulator, you are dissipating (I*R) or 1*2.75 = 2.75 watts of power in the regulator. That's why it is mounted on a heatsink - it gets warm.

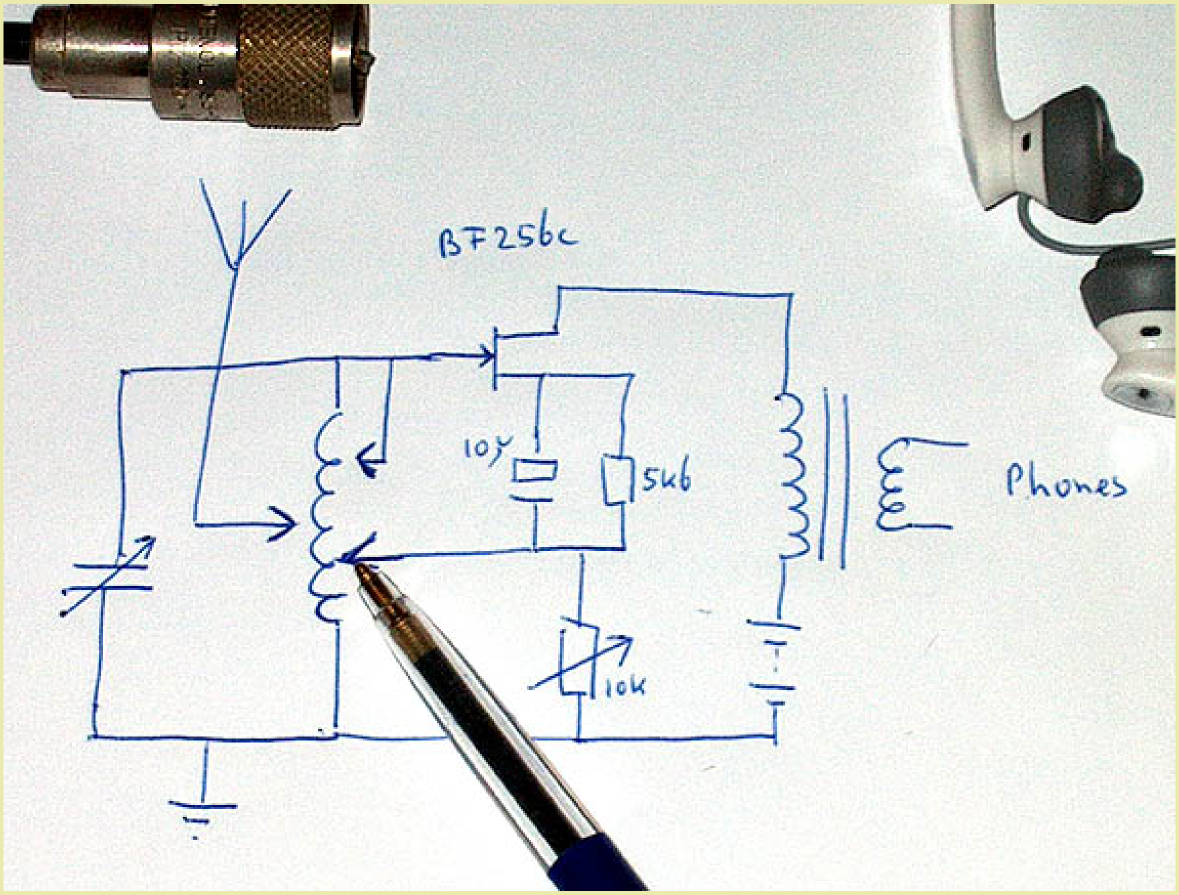
So, the current you can draw from this regulator is limited not only by the regulator IC itself (the 1084 is good for 5A; the 1085 3A), but also by the power dissipated. The heatsink on the BOM is good for 5-7 watts, depending on how hot you're willing to let it get. You can get taller or shorter heatsinks that will fit the PCB if you need more or less power dissipation. And if you're clever you can figure out how to mount it to your chassis for additional heatsinking.

You can see a pair of the earlier version filament converters in this picture of the underside of the "Unnecessarily Complex 300B Amp". They are the two green PCB's...

A VERY SIMPLE RECEIVER

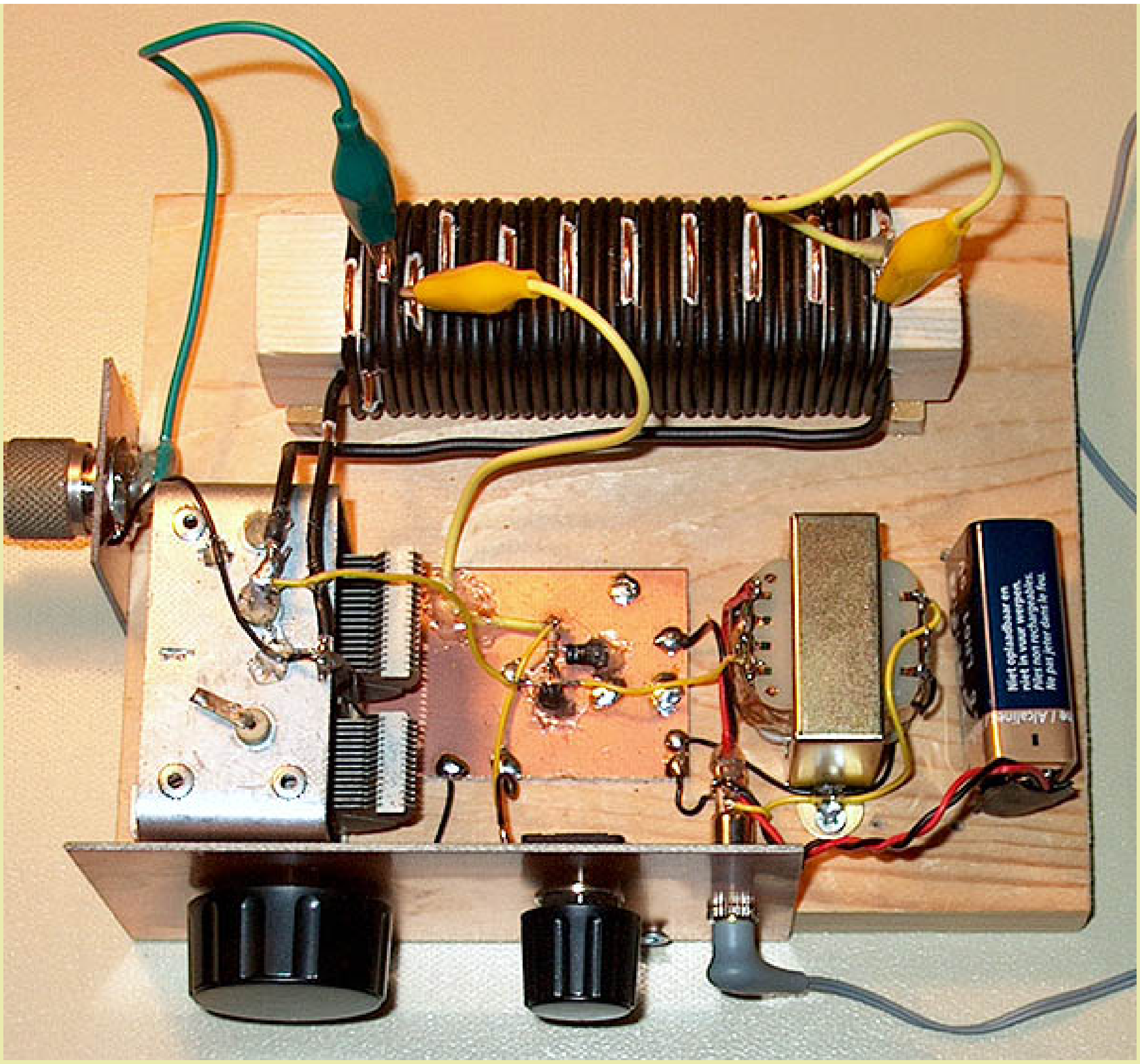
(2005)

KLIK HIER VOOR DE NEDERLANDSE VERSIE



The very simple receiver for the whole shortwave band.
Regenerative control, tuning, band selection, it has everything.
Even a fine tuning by moving your hand towards the coil!

Real Barefoot Technology: very simple with only one active component!
"Barefoot" technology or simple, cheap and harmless technology. It was certainly not the intention to make a good receiver. No, the question was what you can receive with a very simple receiver with only one active component (transistor, tube or fet). Well, that was more than expected. With this very simple receiver, many radio amateur stations can be heard with a wire antenna of 5 meters. The receiver is tested on 80, 40, 30 and 20 meters but the higher frequency bands can also be received. For 160 meter, the coil needs to have some more windings or an extra capacitor has to be switched in parallel with the variable capacitor.



Top view, the coil in use for 80 meter.
Fine tuning by moving your hand from or towards the coil!

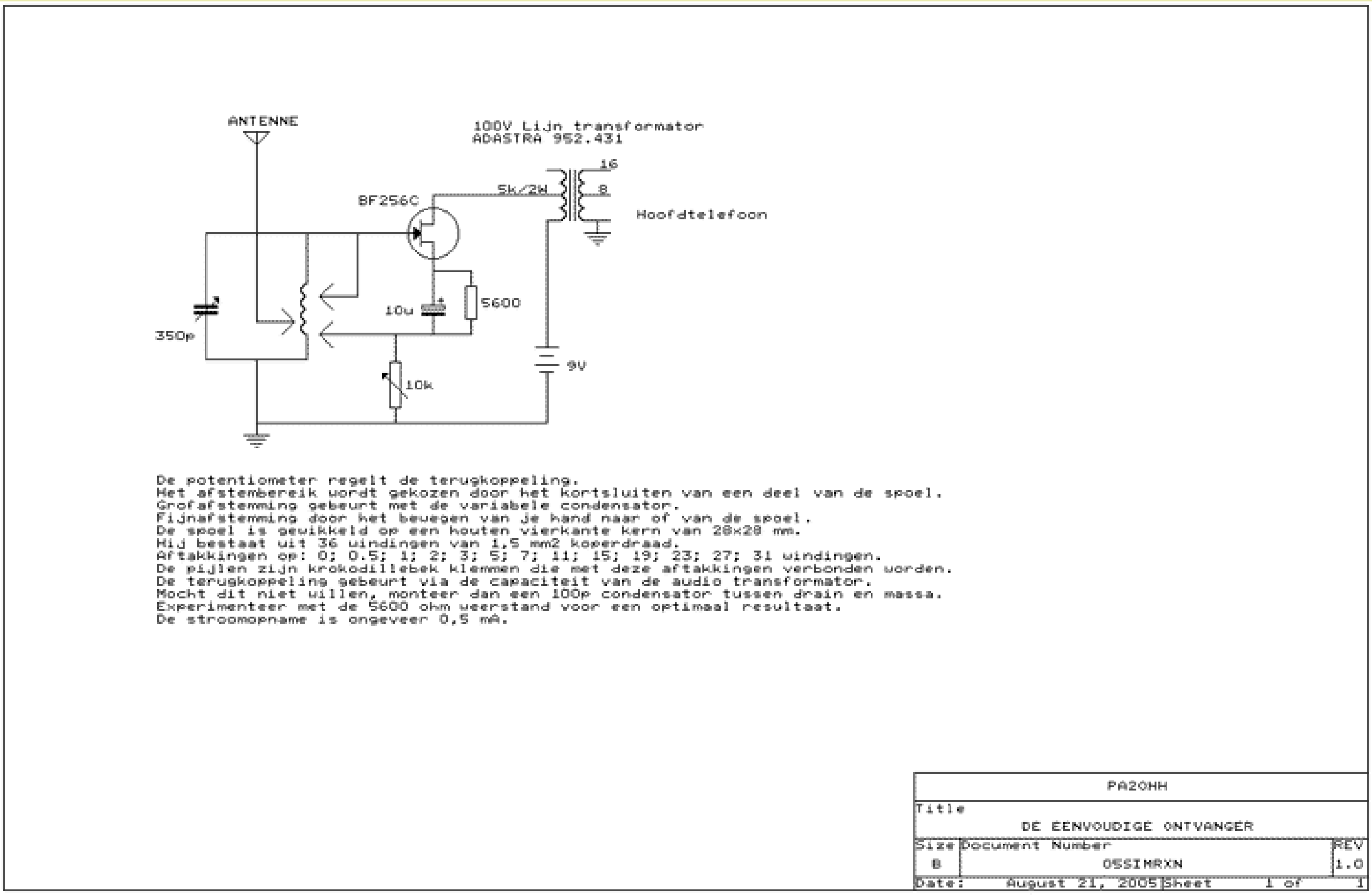
To play and experiments!
The control of such a simple receiver is totally different than working with a complicated transceiver. Especially the fine tuning by moving your hand towards the coil is a special experience, just like searching for the correct taps of the coils. It gives you a good impression about how it was in the beginning of radio. Therefore, experimenting with such a simple receiver is a nice activity, also because you should not expect that it is possible to receive so much with it.

Low battery current!
The battery current is only 0,5 mA. Therefore, the battery life is one year if you use the receiver 2 hours per day!

For beginners???
For a beginner, it is certainly a nice homebrew project and a nice receiver for the strong shortwave broadcast stations. This radio is so simple that the construction of it cannot go wrong! A disadvantage is that you do need sensitive (and expensive) headphones for the reception of SSB signals of radio amateurs, otherwise these signals are very weak. Unexperienced shortwave listeners will have to practice a lot before they can tune this receiver correctly for SSB signals and probably be disappointed because they did expect much more of this simple receiver It was allowed to use only one active component. But when you add an extra LF transistor stage, you can delete the audio transformer of Euro 7.50 and also use less sensitive and cheaper headphones!

Description
The heart of the circuit is the fet BF256c (c type has the highest gain). By means of the 5600 ohm resistor, it works

in the non- linear part of the Id/Vgs characteristic. Experiment with that value in your receiver for better performance. The 10uF capacitor is for decoupling of the resistor, also for high frequencies. Perhaps that you need to add an extra 0.1uF capacitor in parallel for decoupling of the RF frequencies but I did not hear any difference. The regeneration is controlled by means of the 10k potentiometer. Adjust it for maximum sensitivity. The audio transformer is necessary for impedance matching between the fet and the headphones. The 5000 ohm primary tap was selected here at first, later the 10000 ohm. Of course you can use also another transformer. Even a 230 volt / 12 volt transformer from and old mains adapter is often useable, just try it. The headphones used is a Philips, model HS415. Sensitivity is very good, both earpieces are connected in parallel.



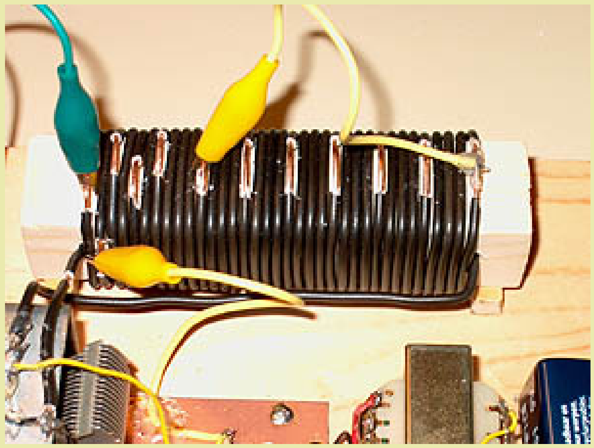
Schematic diagram of the simple receiver.
Sorry for the Dutch text but you will understand it after reading this article.
big diagram

Regenerative control
Regeneration takes place by connecting the source of the fet to a tap of the coil. Regeneration is controlled by means of the 10k potentiometer, less or more signal goes via the potentiometer instead of via the tap of the coil. Regeneration occurs only if the drain has a capacitive coupling with ground. That happens here via the existing capacitances of the audio transformer (primary/secundary) and/or via the battery. If the capacitance is insufficient, connect a capacitor of 10nF between drain and ground, that gives also some extra audio selectivity (attenuation of high tones). You should expect that the adjustment of the regeneration influences the tuning frequency considerably. But in practice, that is not the case.

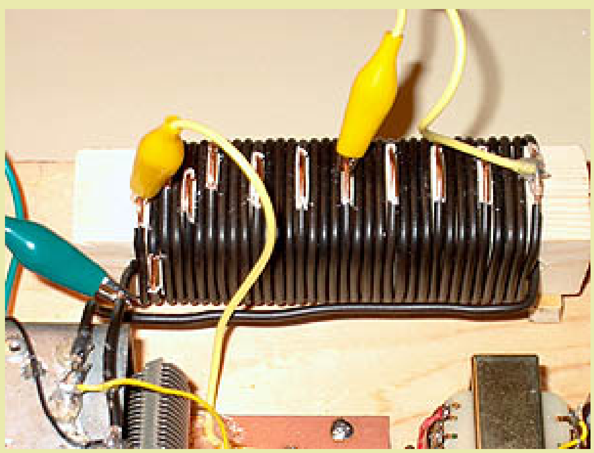
Coarse tuning with the variable capacitor and fine tuning with your hand
The various shortwave bands can be selected by shortening a part of the coil from the top. Coarse tuning can be done with the variable capacitor. There is a very simple solution for the fine tuning: Move your hand towards or from the coil. With this fine tuning, it is possible to tune the whole 30 meter band and also the CW or SSB part of the 40 meter band!

Automatic frequency correction
As you will understand, the stability of the receiver is not so good because there is a direct coupling of the oscillator with the antenna and the construction is very open without any screening. But the fine tuning with your hand is also an automatic frequency correction! You will move your hand automatically to correct for the frequency drift.

The coil
The coil is wound with 1,5mm solid copper wire (black) on a square strip of wood of 28x28 mm. The windings with a tap are pulled upwards a little and the isolation is removed..The antenna, source of the fet and the short from the top are connected to these taps with crocodile clips. The correct tap is determined experimentally by ear. There is also a tap on zero windings. This is located in the middle of the connection between the coil and the ground of the tuning capacitor.



The coil in use for 20 meter.



The coil in use for 40 meter.
In the evening, the antenna is connected to tap 0 (a few cm from ground).
At tap 1 the receiver is overloaded then by the strong signals.

Results
The sensitivity is approximately 4 microvolt on all bands, that will say that CW signals of 4 microvolt can be received without any problem. With some extra effort it is possible to receiver signals of 2 microvolt.
In practice, you can receive CW signals of S6 to S7 and S7 to S8 for SSB. As the majority of signals has at least this strength, there is much to hear! Especially on 80, 40 and 30 meters, the reception is excellent. But also on 20 and 17 meters many signals are heard.
It is recommended to use a low pass filter on 80 meters in the evening (for example an antenna tuner). Otherwise you will have much trouble with whistles caused by the very strong broadcast transmitters on the second harmonic. On the other bands you do not have this problem.

The 5 meter vertical antenna.

WHAT CAN YOU HEAR WITH SUCH A SIMPLE RECEIVER

Below an impression about what you can receive. There is not really tried to receive as many stations as possible, so now and then I listened for a while to some QSO's.

80 METER, 15 AUGUST 2005, 1830 - 1939 GMT	
Listened the first half hour to the transmission of the club station of PI4AA. Excellent signal! The other stations are heard in the second half hour.	
80 meter SSB: PI4AA (excellent, some interference) PE1NXK (weak, no interference) PA2JWN (good, no interference) PA2AD (good, no interference) PA3ESU (good, no interference) PE1ABT (weak, no interference) DL9HAM (excellent, some interference)	**80 meter CW:** G0TMX (very good, no interference) F6EJN (very good, no interference) G3VRU (very good, some interference) SM5COP (very good, no interference) G3SES (good, no interference) G0SZR (good, no interference) OM3KAP (good, much interference) G3SES (good, no interference) DJ4EL (good, some interference)

40 METER, 23 AUGUST 2005, 1852 - 1954 GMT	
Also many long QSO's so that it was difficult to get the calls because they were not given very often or in a foreign languaged.	
40 meter SSB: DH3RS (good, some interference) DL7HKL (very good, some interference) DL4MA (good, some interference) M0JED (very good, much interference) ON4KPR (very good, some interference) M3DOQ (good, some interference) F6FJH (good, some interference) DC4DG (good, some interference) OK1BN (very good, much interference) DF1WR (very good, some interference) OE6RLF (good, some interference) G0CBW (good, some interference)	**40 meter CW:** DJ5MZ (very good, some interference) SM1OII (very good, some interference) IK1JJH (good, some interference) RL3AF (good, much interference) DL7YAV (good, much interference) HA3OD (good, some interference) DL8PG (very good, much interference) UA9UFO (good, some interference) G3HNC (very good, some interference) PC7CW (good, some interference) DL0AU (good, much interference) EA7GV (good, some interference) EA7CJN (good, some interference) DJ6ZM (very good, some interference) HA5BDM (good, some interference) RW3AA/P (good, some interference) DL4CH (good, some interference)

30 METER, 16 AUGUST 2005, 1821 - 1900 GMT en 2014 - 2054 GMT	
There are no SSB stations on 30 meter. In CW, it is much easier to get the calls than in SSB as foreign languages are not a problem in CW.	
30 meter SSB: No SSB stations on 30 meter	**30 meter CW:** EU3DN (good, some interference) OE1ZL (good, some interference) G3JUX (weak, some interference) OE5CSP (good, much interference) ND9M/MM (good, some interference) OM8AG (very good, some interference) LA2U (good, some interference) S59AA (good, some interference) S52VP (very good, no interference) SN25SOL (very good, no interference) IK2WXW (very good, no interference) SQ9I (good, some interference) LY2ER (very good, much interference) DQ5M (good, some interference) YU1FE (very good, some interference) LY2PX (good, some interference) T94DO (good, much interference) GM4KGK (good, some interference) M0NLD (weak, some interference) IZ0FZQ (good, some interference) F5BPM (very good, some interference) JA4FHE (very good!, some interference)

	EA2PA (weak, some interference) F5PRH (good, some interference) G3NQF (very good, some interference) OK2WK (good, some interference) IK0NOJ (good, some interference) UA3QXD (weak, some interference) DL3KVR (very good, some interference) RZ3EA (good, some interference)

20 METER, 19 AUGUST 2005, 1905 - 2009 GMT	
On 20 meter often short QSO's with the calls clearly spelled.	
20 meter SSB: K4KAL (good, some interference) EA7HW (very good, some interference) RL3FT (very good, some interference) SV9GPV (good, some interference) OE4XRK (excellent, no interference) RK3XXA/P (very good, no interference) CN8SG (very good, some interference) S58AL (excellent, no interference) IS6BXV (good, some interference) US4IXQ (excellent, much interference) ER4DX (excellent, much interference)	**20 meter CW:** K4EJQ (good, some interference) W2YJ (good, some interference) UT7LM (very good, some interference) W4PKU (very good, some interference) HA1KXX (very good, no interference) S8IDX (good, no interference) UA3TN (good, no interference) EA5BZJ (very good, some interference) RW6BD (good, some interference) YO4PP (good, no interference) IK1ATK (good, some interference) UA3AO (very good, some interference) US5FA (very good, some interference) YU1XI (very good, some interference)

My frequency scale
The next table is used as a scale to tune to the various bands.
The 5.3 MHz band is an amateurband that is used in the UK.
The sensitivity on 15 meter is less good, the reason is not found yet.

Band	Antenna tap	Source tap	Top tap	Tune (degrees)	Sensitivity
80	3 (2.5wdg)	4 (4.5wdg)	12 (35wdg)	270	4 uV
80	1 (0.5wdg)	3 (2.5wdg)	12 (35wdg)	270	8 uV
5.3 MHz	3 (2.5wdg)	4 (4.5wdg)	12 (35wdg)	365	4 uV
5.3 MHz	2 (1.5wdg)	4 (4.5wdg)	12 (35wdg)	365	4 uV
40	1 (0.5wdg)	2 (1.5wdg)	8 (19wdg)	350	4 uV
40	0 (wire)	1 (0.5wdg)	8 (19wdg)	350	16 uV
30	1 (0.5wdg)	2 (1.5wdg)	6 (11wdg)	355	4 uV
20	1 (0.5wdg)	2 (1.5wdg)	6 (11wdg)	360+95	4 uV
17	1 (0.5wdg)	2 (1.5wdg)	5 (7wdg)	360+90	4 uV

15	0 (wire)	1 (0.5wdg)	5 (7wdg)	360+130	8 uV
12	0 (wire)	1 (0.5wdg)	4 (4.5wdg)	360+120	4 uV
10	0 (wire)	1 (0.5wdg)	4 (4.5wdg)	360+170	4 uV

BACK TO INDEX PA2OHH

The PFR
Portable Field Ready radio
Preliminary manual

Hendricks Kits
KD1JV Designs

Specifications:

Bands : 40 meters, 30 meters and 20 meters
Tuning range: Full band coverage
Mode: CW only

Receiver MSD: 0.2 uV typical
Selectivity : 300 Hz
Receive current, no signal typical:
Active, 47 ma
Idle, 34 ma

Transmitter:
5 watts at 12 volts, all bands
Spurs: - 50 dBc maximum, all bands

5 to 35 wpm internal iambic keyer
Two (2) 63 character keyer memories.

Coax or balanced line output
Built in BLT (balanced line tuner)

Size: 7.3” long, 4.4” wide, 1.6” high. (18.4 x 11 x 4cm)

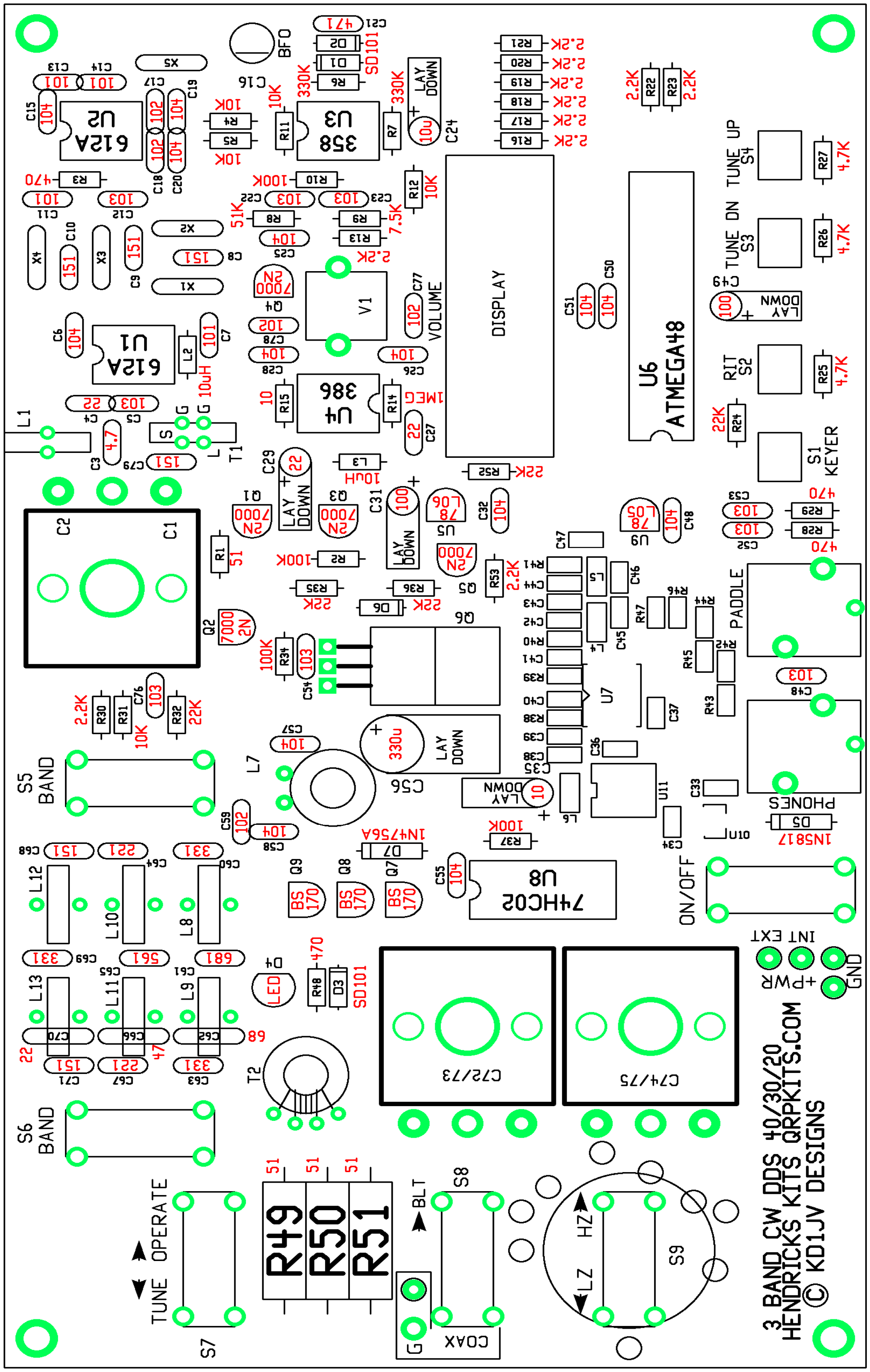
Power supply voltage: 8 volts minimum, 12.5 volts maximum. 12 to 9 volts recommend.

Parts check list:

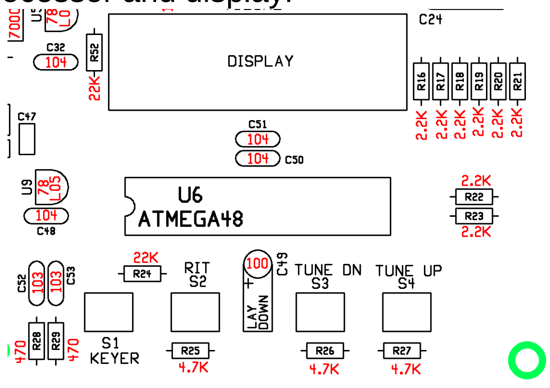
	QTY	VALUE			QTY	VALUE	
	1	10 ohms	Brown, black, black, gold		1	4.7 p NPO	Disk, brown, black dot on top edge
	1	51 ohms	Green, brown, black, gold		3	22 p NPO	Disk, brown, black dot on top edge
	4	470 ohms	Yellow, Violet, brown, gold		1	47 p C0G	Disk, brown, black dot on top edge
	11	2.2 K	Red, red, red, gold		1	68 p NPO	Disk, brown, black dot on top edge
	3	4.7 K	Yellow, violet, red, gold		4	100 p NPO	Disk, brown, black dot on top edge
	1	7.5K	Violet, green, red, gold		6	150 p C0G	Mono, yellow
	5	10 K	Brown, black, orange, gold		2	220 p C0G	Mono, yellow
	1	51 K	Green, brown, orange, gold		3	330 p C0G	Mono, yellow
	5	22 K	Red, red, orange, gold		1	560 p C0G	Mono, yellow
	4	100 K	Brown, black, yellow, gold		1	680 p C0G	Mono, yellow
	2	330 K	Orange, orange, yellow, gold		1	470 p DISK	Disk, brown
	1	1 MEG	Brown, black, green, gold		5	.001 ufd disk	Disk, brown
	1	50K audio	Vertical PCB mount		6	0.01 ufd X7R	Mono, yellow
	3	51 ohm 2W	Green, brown, black, gold		14	0.1 ufd X7R	Mono, yellow
	2	SA612AN	8 pin DIP IC		2	0.01 ufd film	Film, green
	1	LM358N	8 pin DIP IC		1	30 p trimmer	Green
	1	LM386N	8 pin DIP IC		3	poly-variable	Variable capacitor, dual section
	1	74HC02N	14 pin DIP IC		2	10 ufd /16V	Aluminum electrolytic
	1	ATMEGA48	28 pin DIP IC		1	22 ufd /16V	Aluminum electrolytic
	1	78L05	TO-92 plastic		2	100 ufd /16V	Aluminum electrolytic
	1	78L06	TO-92 plastic		1	330 ufd /16V	Aluminum electrolytic
	1	1N5817	Plastic diode shottky rectifier, 1A		4	8 pin DIP sockets	
	1	1N4756A	Larger glass diode, 47V 1W zener		1	14 pin DIP socket	
	3	SD101C	Glass diode, fast shottky		1	28 pin DIP socket	
	1	FQPF7P06	TO-220 plastic P MOSFET		2	FT37-43	Ferrite core, gray or black
	5	2N7000	TO-92 plastic N MOSFET		6	T37-2 Red	Powdered iron core
	3	BS170	TO-92 plastic N MOSFET		2	T37-6 Yellow	Powdered iron core
	1	4 dig LED	4 digit multiplexed display module, hi eff		1	T100-2 Red	Powdered iron core
	1	Super bright	LED clear		4	6mmx13mm tack	Push button switch
	2	10 uhy rfc	Brown, black, black, gold		6	DP3T slide switch	
	5	4.9152 MHz	Crystals HU-49US		2	Stereo jacks	
	1	Power jack	2.1 mm pin		3	Knobs	
	1	BNC jack			1	Red filter	
	2	Binding posts	1 Red, 1 Black		1	PC board	
	4	spacers	3/8” # 4 threaded hex spacers		3		Sets of vari-cap mounting hardware
	8	1/4” 4-40 screw			4	#4 lock washers	
		#30, #28, #24	Magnet wire, #24 hook up wire		6	#4 Nylon washers	

			These parts are premounted				
	1	AD9834BRUZ	DDS		3	22 K	0805 chip resistor
	1	50.00 MHz clk	Clock oscillator		1	22 p	0805 NPO chip resistor
	1	10 uhy	1206 Choke inductor		2	8 p	0805 NPO chip capacitor
	2	1.5 uhy	1206 Choke inductor		2	150 p	0805 NPO chip capacitor
	1	815C35UA	3.5V low drop out regulator		1	220 p	0805 NPO chip capacitor
	3	270 ohm	0805 chip resistor		4	0.01 ufd	0805 X7R chip capacitor
	1	3.9 K	0805 chip resistor		3	0.1 ufd	0805 X7R chip capacitor
	3	10 K	0805 chip resistor				

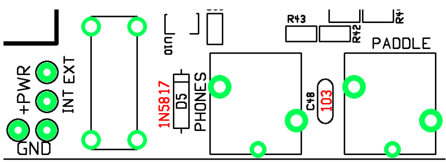
Parts placement overview. Print this page out for handy reference while building.

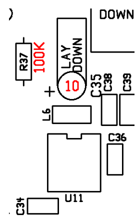


Group 1 assembly, Microprocessor and display:



- R16 to R23 - 8 places. 2.2K (RED/RED/RED/GLD)
- R24, R52 – 22 K (RED/RED/ORG/GLD) – be careful not to mix up the 2.2 K and 22 K !
- R25 to R27 – 4.7 K (YEL/VOL/RED/GLD)
- R28 and R29, 470 ohms (YEL/VOL/BRN/GLD)
- C32, 48, C50, C51, 0.1 ufd (104, mono, yellow)
- C52,C53 0.01 ufd (103, mono, yellow)
- C49, 100 ufd / 16V Long lead is plus. Bend leads at right angle to part and lay part flat to board along extended outline. (You will do this with all the other electrolytic caps on the board too)
- U9, 78L05. Do not mix up with the 78L06 or 2N7000 which are in same TO-92 package.
- 28 pin dip socket at U6
- LED display module. This will only go in one way, due to missing pins on display and corresponding missing holes on board. Mount extended from the surface, let pins protrude only 1/32" on the far side of the board for soldering.
- Four (4) TACT switches. These have the long red actuators.



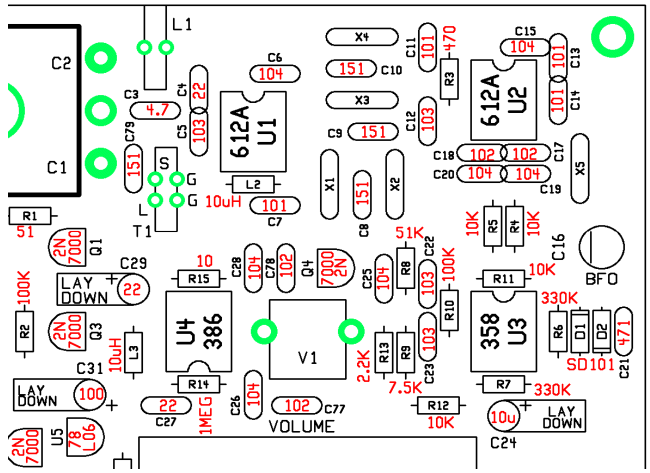


- D5, 1N5817 diode, black body. Band on part goes towards line on part outline.
- C48, 0.01 ufd (103)
- Paddle and phone jacks.
- DP3T slide switch. (ON/OFF)
- C35, 10 ufd / 16V again, long lead is plus and lay down part flat to board. Located above SMT parts, next to R37.

Group 1 smoke test:

- Install the ATMEGA48 microprocessor chip into the U6 socket.
- Connect up a 9 to 12 volt power supply to the power input pads next to the on/off switch. A 9 volt radio battery would be adequate for this test.
- Apply power to the board and turn on power switch if it is not already on.
- The LED display should light up with four "8"s for a couple of seconds. This is the display test. Then the display should display "40" for another couple of seconds (indicating the band), then 030.0 (this is the frequency)
- Clicking closed the Tune UP or Tune DN switches should make the display increment or decrement.
- Clicking the RIT switch should make the left most decimal point on the display light up.
- The DDS chip should also be working at this point. This can be tested with a frequency counter connected to the R39/R41 junction at U7 or general coverage receiver tuned to about 2.114 MHz with a short pick up lead for an antenna placed near the DDS chip (U7)

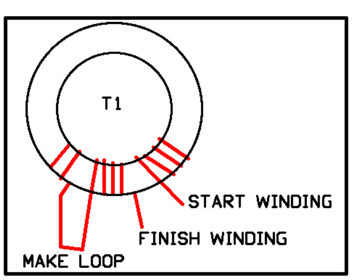
Group 2 Assembly, receiver section:



	R15	10 ohm	BRN/BLK/BLK			C3	4.7 p	NPO, DISK	BROWN
	R1	51 ohm	GRN/BRN/BLK			C4,C27	22 p	NPO, DISK	BROWN
	R3	470 ohm	YEL/VOL/BRN			C7,11,13,14	100 p (101)	NPO, DISK	BROWN
	R13	2.2 K	RED/RED/RED			C8,9,10,79	150 p (151)	NPO, DISK	BROWN
	R9	7.5 K	VOL/GRN/RED			C21	470 p (471)	DISK	BROWN
	R4,R5,R11,R12	10 K	BRN/BLK/ORG			C17,18,77,78	.001 u (102)	DISK	BROWN
	R8	51 K	GRN/BRN/ORG			C22,23	0.01 u (103)	FILM	GREEN
						C5, C12	0.01 u (103)	MONO	YELLOW
	R10	100 K	BRN/BLK/YEL			C6,15,19,20	0.1 u (104)	MONO	YELLOW
	R6,R7	330 K	RED/RED/ORG			C25,28	0.1 u (104)	MONO	YELLOW
	R14	1 MEG	BRN/BLK/GRN			C24	10 u/16V	LAY FLAT	ELECTRO
	L2,3	10 uHy	BRN/BLK/BLK/GLD			C29	22 u/16V	LAY FLAT	ELECTRO
						C31	100 u /16V	LAY FLAT	ELECTRO
	D1,2	Glass diode	SD101			U5	78L06		
	U5	6V reg	78L06			Q1,2,3,4	2N7000	MOSFET	

NOTE: L2/L3 look like resistors, but the body is a little shorter and fatter. Do not mix up with 10 ohm resistor. Also, be careful not to mix up 51 ohm resistor with 1 MEG, as colors are very similar.

	X1,2,3,4,5	Crystals	Tack solder case to solder pads next to crystal case. Running fine grit file along
			edge of crystal case will make the solder easier to stick.
	C16	30 p trimmer (Green)	Make sure flat side of trimmer faces line on outline.
	U1,2,3,4	8 pin sockets	
	V1	50 K variable resistor	Solder mounting tabs to board.
		The following parts	mount on Bottom of board
	C1/2	Poly-varicap	Mounts on bottom of board. Use 2.5mm washers between board and cap.
	L1	T37-2 (red core)	40 turns, 24” of # 30 wire
	T1	T37-2 (red core)	40 turns secondary, 5 turns primary see next page for winding details.



L1 and T1 are mounted on the bottom side of the board!
T1 winding: Wind with #30 wire. T1 must be wound in a specific way so that the “hot” end of each winding will end up on the same side of the core and line up with the proper holes in the board. Wind the core in a counter clockwise direction, passing the wire down into the hole from the top side of the core as you hold it. At the end of 40 turns, make a short loop and continue winding five (5) more turns. Snip the loop to separate the windings and tin the wire ends. Place into the board so one end of the four turn “link” (primary) goes into the pad marked “L” and one end of the 40 turn secondary goes into the pad marked “S”. The two pads on the other side of the core are both ground.

Group 2 smoke test:

Install U1 and U2 (SA612A) into sockets
Install U3, LM358
Install U4, LM386 NOTE : U4 pin 1faces “down”, the opposite direction of U1, U2 and U3

The receiver section is now done and should now be functional. Give the BFO trimmer (C16) about a ¼ turn from its factory setting. If you look closely in the trimmer hole, you will see an arrow at one end of the screwdriver slot. When the arrow points towards the flat side of the body, it is a maximum capacitance. When it points to the round end opposite the flat end, it is at minimum. Using leads connected to the BNC connector, you can tack these wires across R1 (make the connections on the bottom of the board) in order to connect up an antenna. The end of R1 near Q1 is the signal side of the resistor. Apply power to the board and you will be receiving in the 40 meter band. Adjust the Rx tuning cap (C1/2) for best band noise or signal. The peak should occur near full counterclockwise rotation. Plugging in a paddle to the paddle jack and then operating the paddle should result in hearing the side tone sending dits and dahs. The Keyer function switch annunciations can now also be heard.

DDS frequency calibration and precise BFO setting adjustment:

If you have an accurate frequency counter, the DDS frequency can be calibrated. Without calibration, the operating frequency maybe off as much as +/- 200 or 300 Hz on the 20 meter band and to lesser extent on the lower bands. This is due to variations in the reference clock oscillator for the DDS chip. Calibration is done at 10.000,000 MHz, so it could be possible to zero beat WWV, but it is better left alone if an accurate frequency counter is not available. It is also possible to tweak the IF offset frequency so that it is centered in the passband of the crystal filter. This adjustment is done with the aid of an Oscilloscope, which could be a virtual one running on PC, as all you need to see is audio frequencies. The IF offset adjust mode is also used to set the BFO trimmer to match the side tone of the rig and this can be done by ear.

Entering Calibration modes:

While holding the DOT paddle and KEYER switch closed, turn power on to the board. The LED display will read [CAL.r].

Reference frequency calibration:

A frequency counter connected to the TP1 test point near the DDS chip will now read about 10 MHz. Use the Tune up and Tune down switches to adjust the frequency to be exactly 10.000,000 MHz. Once this is done, store by clicking the KEYER switch. Or you can skip this adjustment by clicking the KEYER switch. This will store the default values and advance to the offset adjustment

IF offset adjust and BFO trimmer set.

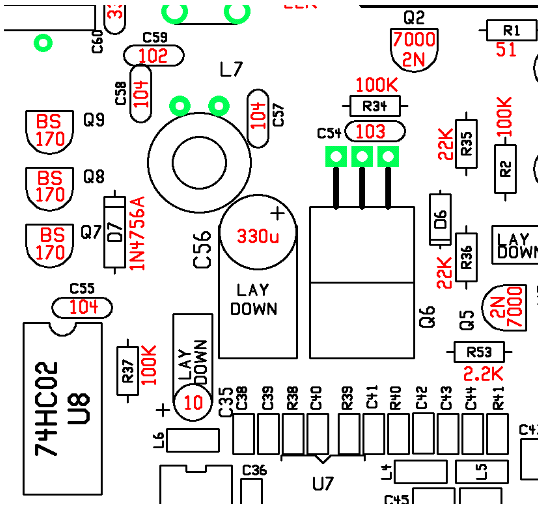
Once the KEYER switch has been clicked, the LED display will now read [CAL.o]. Connect an Oscilloscope to Pin 7 of U3. You will see the audio product detector beat note on this pin. If you do not have an Oscilloscope, do not make any adjustments to the IF offset frequency and just go do the BFO adjustment.

Tune through the pass band of the crystal filter using the tuning switches. You will likely see the amplitude of the signal peak a little at the edge of the pass band, just before the amplitude rolls of sharply. Tune to one end of the pass band, the point the amplitude of the signal starts to roll off. Count how many clicks of the tuning switch it takes to get to the other end of the pass band. Divide that number by 2 and tune back up or down depending on which way you went initially by that number of clicks to center the frequency in the pass band of the filter.

BFO adjustment:

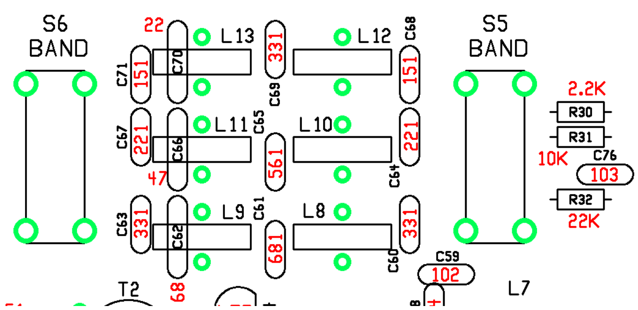
Plugging headphones into phones jack and you will hear the side tone and BFO beat note. Adjust the volume control until they have about the same volume. Adjust the BFO trimmer until both tones are the same. The tones will wobble when they get close to being equal and seem to merge when they are. This can also be seen on an Oscilloscope. Once you match the tones, store the adjusted IF offset or leave the default values in place by clicking the KEYER switch The rig will now reset.

Group 3 assembly: Transmitter section.



	R53	2.2 K	RED/RED/RED
	R35, 36	22 K	RED/RED/ORG
	R34,R37	100 K	BRN/BLK/YEL
	D6	Not used	
	D7	1N4756A	Glass diode, large
	C54	0.01 ufd (103)	MONO, Yellow
	C55, 58, 59	0.1 ufd (104)	MONO, Yellow
	C56	330 ufd/16V	Electro lay flat
	Q5	2N7000	TO-92
	Q5,7,8,9	BS170	TO-92
	Q6	FQPF7P06	TO-220
	U8	14 pin socket	74HC02A IC
	L7	8 T on FT37-43	8” #28 black core

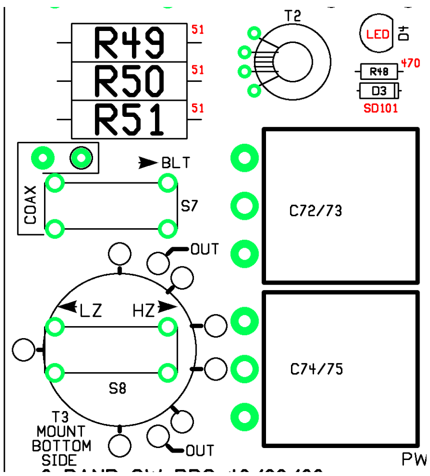
Group 4, low pass filters:



	R30	2.2 K (RED/RED/RED)	
	R31	10 K (BRN/BLK/ORG)	
	R32	22 K (RED/RED/ORG)	
	C76	0.01 ufd (103, mono)	
	C68,C71	150 pfd (151, mono)	
	C67,C64	220 pfd (221, mono)	
	C69,C63,C60	330 pfd (331, mono)	
	C65	560 pfd (561, mono)	
	C61	680 pfd (681, mono)	
	C62	68 pfd (68, disk)	
	C66	47 pfd (47, disk)	

	C70	33 pfd (33, disk)	
	Low pass filter	**Coils mount from bottom**	**Of board!**
	L8	17 turns on T37-2	Red core 10” #28
	L9	19 turns on T37-2	Red core 10” #28
	L10	13 turns on T37-2	Red core 8” #28
	L11	15 turns on T37-2	Red core 8” #28
	L12	14 turns on T37-6	Yellow core 8” #28
	L13	18 turns on T37-6	Yellow core 10” #28
	S4,5,6	DP3T slide switch	

Group 5, SWR bridge and balanced line tuner:



- R48, 470 ohm (YEL/VOL/BRN)
- R49, R50, R51 - 51 ohm, 2 watt (GRN/BRN/BLK)
- D3 – SD101, small glass diode
- D4 – clear LED – note flat side on part and outline, bottom of the led 5/16” from the surface of the pc board
- S7 – DP3T slide switch
- S8 – DP3T slide switch – this mounts above T3.
- T2 – Black FT43-37 core. Wind 25 turns as secondary and 5 turn primary in middle between ends of the secondary turns. Secondary ends go to two outside holes and primary the two middle holes.
- T3 – Mounts on bottom of board. Core is about same diameter as the mounting holes for the wire connections. See below for winding and mounting details.
- C72/73 and C74/75 Poly-variable capacitors. Mount on bottom of board with nylon washers between board and body of capacitor.

Winding T3:

- Cut a 36” (3 foot) length of the #24 wire.
- Wind 16 turns on the T100-2 core (this is the large red core)
- Start the winding of the core by passing the starting end of the wire into the hole from the top (side facing you as you hold it) and wind by passing the long end of the wire up from the bottom of the core. Wind the rest of the turns in a counter clock wise direction. Winding the core in this fashion will make the ends of the wire line up with the staggered holes in the board.
- Pull the 8th turn slightly away from the middle, outside of the core a little.
- Scrape away the insulation on the wire of this 8th turn, just a little near the middle of the core.
- Cut a 2” length of the #24 wire and tin one end.
- Attach this wire to the 8th turn on the core. Make a small, half loop on the end of the wire and lightly crimp to turn on core, then solder. See photo.

- Cut a 24” length of the #24 wire and wind 12 turns inter-weaved between the first winding and centered around the tap you just made, so there are six turns on either side of the tap.

- Now cut a 18” length of the #24 wire and wind three (3) turns on either side of the tap, for a total of six (6) turns. This winding will also be inter-weaved between the other two windings.
- The core is mounted to the bottom of the board and the wires are soldered from the top. Suspend the core slightly off the bottom of the board so that the wires do not touch the ends of the switch mounted above it. In fact, it is a good idea to snip the ends of the switch terminals flush to the board before mounting the coil. Be careful not to put the High Z winding into the pads marked “OUT”, as these pads will connect to the binding posts on the cabinet.

Final tests:

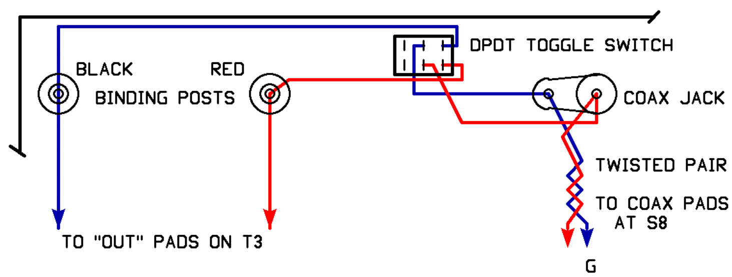
The board is now complete and the only thing left to test is the transmitter. Connect the BNC jack to the COAX terminals on the board by S9. Now connect a watt meter and dummy load to the jack. Make sure both BAND switches are set to the same band, you might as well start with 40 meters. Set the Tune / Operate switch to the operate position and the COAX / BLT switch to the coax position. Apply power to the board and send some dots. There should be some power output showing on the watt meter. If not, remove power and start looking for missing solder connections, that the insulation on the toroid coils has been soldered through and that both band switches are in the same position. If you see power output, go on and check the other two bands.

Power output

Power output is influenced by both power supply voltage and the way in which the turns on the coils are spaced around the core. To measure full power output, put the rig in straight key mode by turning power on to the board with the dash paddle closed or use a straight key. If using a paddle, the dot paddle will now key the transmitter on and off. With a 12.0 volt supply, power output should be close to 5 watts on all bands. If power output is higher than 5 watts, move some of the turns on L8, L10 or L12 (depending on the band) closer together and recheck the power output. Repeat if needed to get close to 5 watts output.

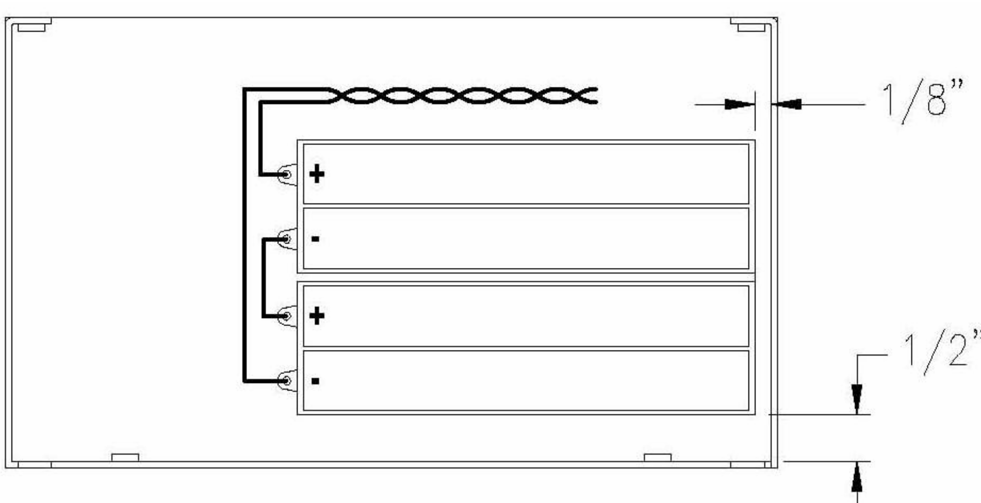
Mounting the board in the cabinet and final wiring:

- Solder the end of a 4.5" length of hook up wire to each of the pads labeled "OUT" under T3. These wires attach to the bottom side of the board. Since T3 covers these holes, the solder connections are made from the top of the board.
- Tape the red acetate filter to the inside of the led window.
- Slide the board into the top piece of the cabinet at an angle with the phone jacks at the front of the board down. To ease mounting, place all slide switches to the center position. Be careful not to bend the SWR led.
- Center the phone/paddle jacks in the chassis holes, and secure the board with the 4-40 x 1/4" screws and lock washers.
- Attach the nylon spacers to the tuning caps with the screw and 2.5mm lock washer. A small drop of super glue into the screw hole on the tuning cap will help keep the screw from coming loose.
- Place the three knobs on the tuning caps. Push the brass knob extension all the way down onto the volume control and secure the volume control knob.
- Mount the two binding posts, DPDT toggle switch, coax jack and external power jack to the rear of the cabinet.
- Wire up the binding posts, switch and coax jack as shown in the diagram below. The wires going from the coax jack back to the board should be tightly twisted together and take a direct path back to the pads on the circuit board.



- Twist two 8" lengths of hook up wire together.
- Solder to external power jack
- Solder the other end to the EXT and GND pads next to the On/Off switch
- The wire for connecting to the power jack to the board should be routed along the outside edge of the board.

Battery Mounting



BOTTOM HALF – FRONT

Operation:

Power supply:

The PFR rig should be powered by no more than about 12 volts and no less then 8 volts. If a 13.8 volt bench supply is used to power the rig, two silicon rectifier diodes should be added in series with the positive supply lead to drop the voltage down closer to 12 volts. This will ensure the rig does not put out more than about 5 watts. 5 watt output at 12 volts was chosen as this is the typical voltage a gel-cell battery settles down to after it has been removed from its charger. Below 8 volts, the 6 volt regulator for the receiver will start to loose regulation.

Power ON:

The power switch has three positions. OFF, Internal (battery) power and External power.

When the rig is first turned on, the display will show all “8”s for a couple of seconds. This is the segment display test. Then the display will indicate the currently selected band, “20”, “30” or “40”. The band numbers will be displayed for another couple of seconds, then the display will change to show the operating frequency. Since only four digits are available, only the 100 kHz to 100 Hz digits are displayed. MHz digits are implied by the currently selected band. The initial operating frequencies loaded when the rig is powered on or the band is changed are 7.030,000 MHz for 40 meters, 10.110,000 MHz for 30 meters and 14.060,000 MHz for 20 meters.

Power save mode:

After about 5 minutes of no switch activity the rig will go into a power save mode by blanking the display, with the exception of the decimal point, and the processor is put to sleep. This will reduce current from 47 ma to 34 ma. Not a huge current savings, but if the rig is being run on batteries, every ma counts. The rig will “wake up” if any switch (other than Band) or the paddle is used.

Selecting operating band:

Two slide switches are used to select the operating band. Both switches MUST be in the same band position for proper operation. The band switch located near the top, center of the cabinet tells the processor which band you want to use and will indicate the selected band on the display for a second when the band is changed or on power up, as noted above. The switch located near the top, left of the cabinet is used to connect the output of the low pass filter to the antenna. If the two band switches are not in sync, there will be no signals in the receiver and the transmitter might be damaged if you transmit at this time.

After you change bands, you must re-peak the receiver input with the Rx peak control.

Tuning:

Tuning is done with two push button switches. These switches are operated best by “clicking” them to the side, rather then pushing straight down. Tuning steps are in 50 Hz increments. A momentary click of the switch will change the frequency by 50 Hz. Since the display only has 100 Hz resolution, it will take two clicks of the switch to see a change of frequency on the display. Holding one of the tuning switches closed for longer than about one (1) second will start an auto tune mode, where the frequency will change in 100 Hz steps at a rate of about 10 steps per second, so long as the switch is held closed. When the switch is released, normal 50 Hz “one click” tuning is restored.

Tuning limits:

Tuning is restricted to be within the currently selected ham band. This is to prevent out of band transmission. Full band coverage is available. 7.000,000 to 7.300,000 on 40, 10.100,000 to 10.150,000 on 30 and 14.000,000 to 14.350,000 on 20. SSB signals can be copied on 40 meters but not on 20, as receive is always lower sideband. Even on 40M where the sideband modes match, SSB signals will be hard to copy due to the narrow CW filter used.

RIT (receiver incremental tuning)

Clicking the RIT switch will activate RIT. The left most decimal point on the display will light when you are in RIT mode. When in RIT mode, the receive frequency is changed by the tuning switches and the transmit frequency stays were it was when RIT was activated. Clicking the RIT switch again will exit RIT mode and restore the original receive frequency.

DFE mode (direct frequency entry)

This mode allows you to go directly to a specific frequency by entering it in with the paddle. Clicking and holding closed the RIT switch for longer than one (1) second will activate this mode. The display will blank when DFE mode is enabled. Enter the frequency you wish to go to, starting with the 100 kHz digit and finishing with the 100 Hz digit. As each digit is entered, it will be shown on the display and shift from right to left as additional digits are entered. If a number is not recognized, a “?” will

be sent by the side tone. Once the 100 Hz digit is entered, the rig will re-tune to that frequency provide it is within the normal tuning limits of the current band. If it's outside the band, the frequency at which the rig was tuned to when DFE was enabled will be restored. If you make a mistake or wish to exit the DFE mode at anytime before the 100 Hz digit is entered, you can escape by clicking any of the switches.

Note: DFE mode is not available in straight key mode or if RIT is on.

KEYER switch:

The keyer switch is used to access various keyer functions. Which function is selected is determined by how long the switch is held closed. Keyer functions are selected in this order: send message, change keyer speed, enter messages and select iambic A or B mode of operation. Note: When in straight key mode, none of the keyer switch functions are available, with the exception of sending keyer message 1, assuming a message is already stored in that location.

Sending a Message:

Two, 63 character (including word spaces) Morse messages can be stored in memory. One of these messages can be sent by first clicking and releasing the KEYER switch and then tapping the DOT paddle to send message one, or tapping the DASH paddle to send message two. This must be done within 1 second of releasing the switch or the change code speed mode will be activated. Once a message has started sending, it can be terminated by closing the DOT paddle. If a character is being sent at the time of dot or dash closure, it must be held closed until that character has finished being sent.

When in straight key mode, only message 1 is available, as the DASH input is always grounded by the straight key plug.

Changing keyer code speed:

If sending a message has not been selected using the paddle after clicking and releasing the KEYER switch, speed change mode will be activated. The current code speed is shown on the display as [C xx], where xx is the current speed. Keyer speed is changed by closing either the DOT paddle to increase speed or closing the DASH paddle to decrease speed. The selected speed is shown on the display. Once the desired speed is indicated on the display, release the paddle and wait about two (2) second and speed select mode is automatically exited.

Storing a message:

Holding closed the KEYER switch for two (2) seconds will active the message entry mode. Release the switch when the letter "M" is annunciated by the side tone. The receiver is then muted and you can now start to enter your message by using the paddle. If you accidentally activate this mode and do not wish to enter a message, click the KEYER switch to abort before touching the paddle. The Letter "X" will be annunciated and the rig will go back to normal operation.

Up to 63 characters (including word spaces) may be entered. If you exceed this limit, the letters "EM" will be annunciated by the side tone and you will have to start again. Note that "ideal" letter and word timing is used to determine letter element groups and word groups. Of these two, the letter timing is most critical. If do not pause long enough before starting a new letter, a letter space will not be detected. If you pause too long, it will be interpreted as a word space. It may take some practice to enter a message correctly. I ensure a word space is inserted, it is best to pause somewhat longer than you normally would between word letter groups.

When you have finished entering the message, click the KEYER switch. The message you have entered will be sent by the side tone so you can check the accuracy of the message. If it sounds good, store it by closing either the DOT or DASH paddle. DOT will store it into message location 1 and DASH into location 2. If you wish to redo the message, click the KEYER switch again. "EM" will be annunciated by the side tone and you can now re-enter the message.

Selecting Iambic A or B modes.

Iambic A mode is the default keyer mode. To switch to B mode or back to A mode, hold the keyer switch closed for about four (4) seconds until the letter A or b appears on the display (b looks like a 6 on the display) then release the switch. The letter which appears on the display will be the mode the keyer will be set to when you release the switch.

The difference between A and B modes:

In A mode, if both paddles are closed at the same time, alternating code elements are sent. If you close the dash paddle first and then hold both the dash and dot paddle closed, the keyer will send dah-dit-dah-dit-dah so long as the paddles are held closed. When the paddles are released, the keyer will simply stop sending at the end of the code element which might be being sent at the time the paddles are released, if any.

In B mode, alternating code elements are also sent when both paddles are closed, but this time an extra and opposite code element will be tacked on the end of the string when the paddles are released. Therefore, so send a letter such as "K", you just have to close the dash paddle first, then tap the dot paddle and dah-dit-dah will be automatically sent. In A mode to send this same letter you would have to keep the dash paddle closed until the second dash started to be sent before releasing the paddle.

In a strict implementation of B mode, any time both paddles are sensed to be closed at the same time would generate this extra element. This can lead to the extra element being sent when you don't intend one to be sent because it is easy to get ahead of yourself. Therefore, the B mode implementation used in the PFR only senses if both paddles are closed during the inter-element space. This makes controlling whether you want an extra element or not easier to control. It is also easier to implement in software.

Both A and B modes have dot and dash memory while an element is being sent. So, if you tap the dot paddle while a dash is being sent, the dot will be sent after the dash is finished and vice-a-versa.

Straight key mode:

If a monaural plug is in the paddle jack at power up (the sleeve grounds the dash input pin), the rig will power up in straight key mode. This allows using either a straight key or external keyer. While in straight key mode, none of the keyer switch functions will be available. If a message has been previously stored in the keyer memories, only memory location 1 will be available, as this is selected with the dot input pin, now controlled by the straight key.

Using the SWR bridge and BLT tuner:

Note that S8, S9 and S10 are three position switches but only two positions are used. The two positions to the left are the same. When mounted in the case, only two positions will work.

Sliding S8 to the TUNE position switches in the SWR bridge. The LED will now indicate the relative amount of SWR. The brighter the LED, the higher the SWR is. When the LED is not lit or is very dim indicates 1:1 SWR.

S9 is used to switch between a direct coax connection to the BNC jack or the BLT (balanced line tuner). The Coax position is of course used if you are using a resonate, coax feed antenna or an external tuner. The BLT position is used when the built in tuner is desired and is normally used with ladder line feed antennas, but can also be used for end feed antennas or matching coax feed antennas which need a little tweaking.

Before transmitting, adjust the TUNE and LOAD capacitors for best band noise or signal strength. Now switch from Operate to Tune mode with S8, if your not already in the tune position. Now transmit (there is no “always on” tune mode, so just send a string of dits or dahs) and fine tune the TUNE and LOAD capacitors so that the SWR LED gets very dim. It may not be possible to make the LED go out completely do to leakage and minor unbalances in the bridge. The tuning of the two capacitors are interactive. If you can not get a good SWR null, try using low impedance setting of S10.

Using the BLT with end feed wire antennas or coax.

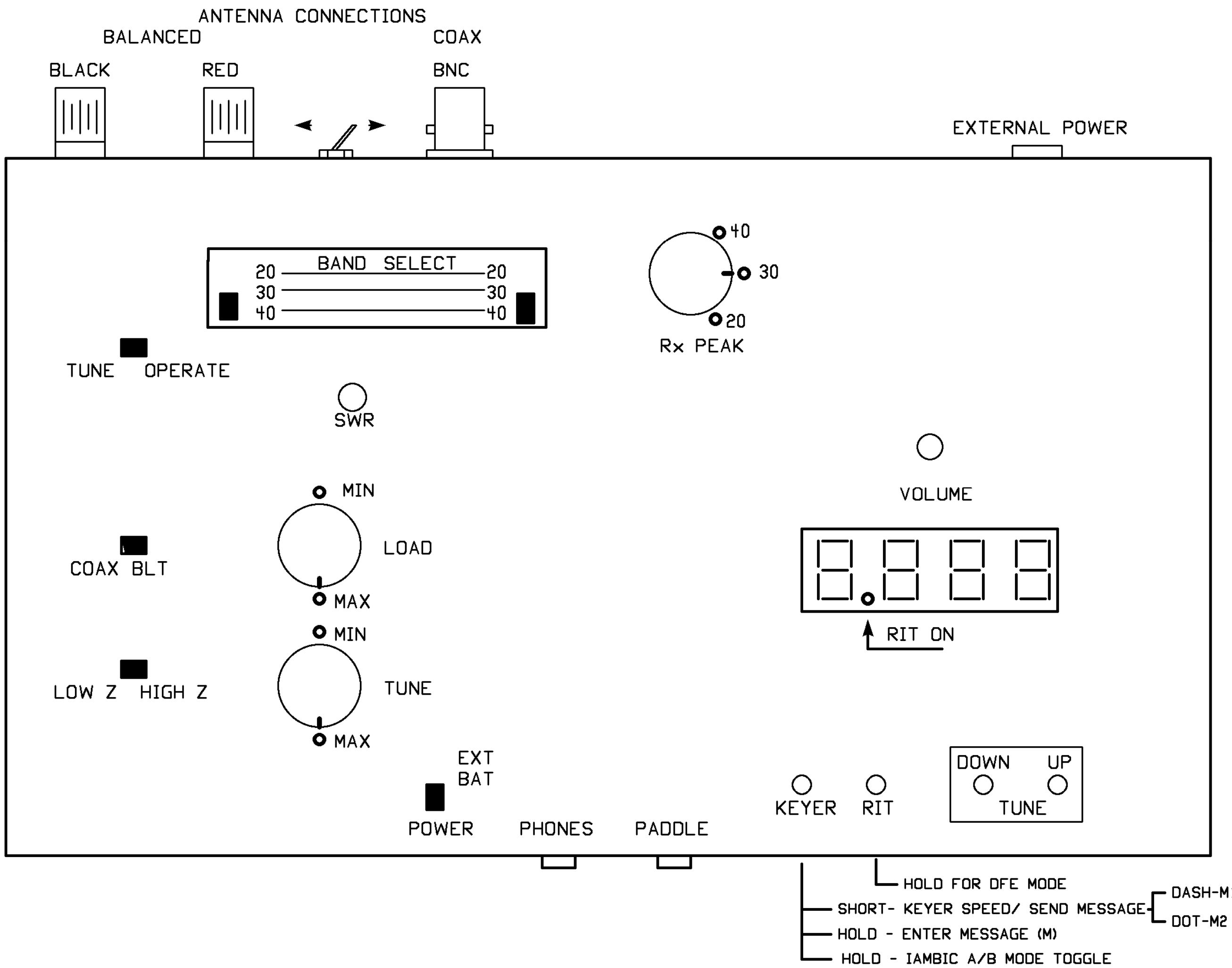
The DPDT switch on the back of the enclosure is wired so it will ground the black balanced line binding post and connect the Red post to the coax jack. End feed wire antennas can now be connected to the Red binding post and a counter pose to the Black post. Use the High Z position of S10 if the wire is near a 1/2 wave in length. Use the Low Z position if the wire is near a ¼ wave or less in length. The Low Z position is also used when using the BLT to match a coax feed antenna.

Using a speaker instead of headphones:

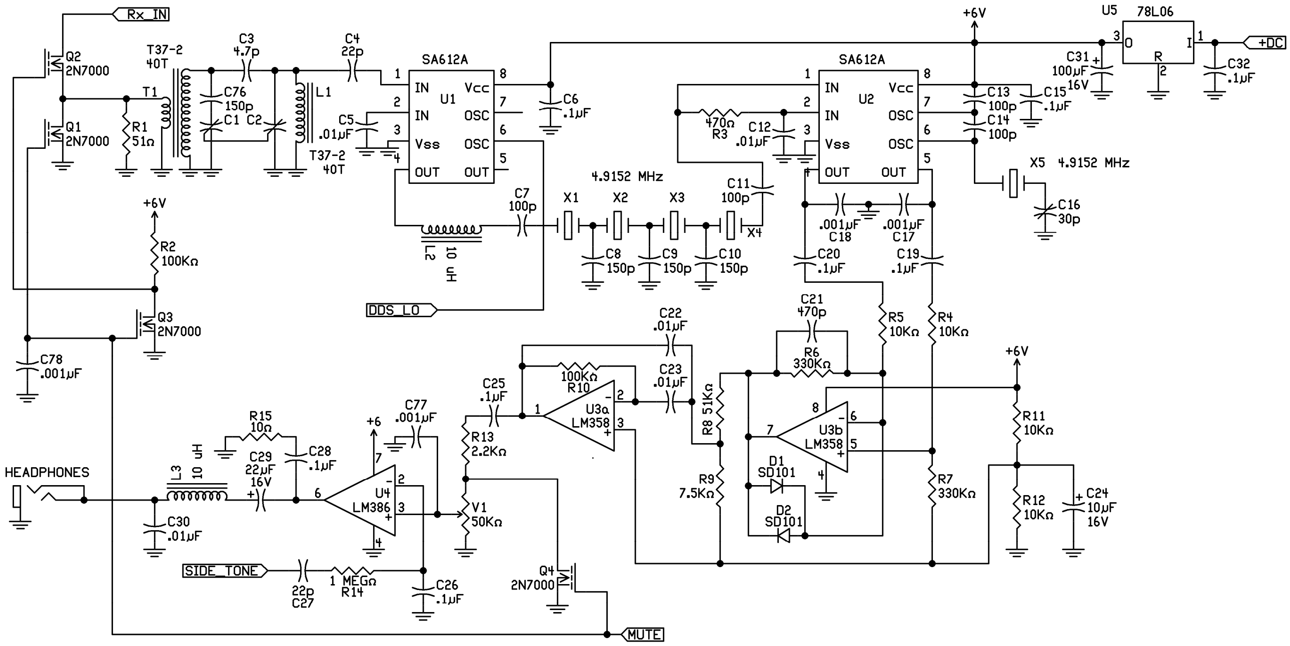
The amount of current the audio amplifier can deliver to a speaker is limited by the current available from the 78L06 regulator. A small, efficient speaker at low or modest volume should be alright. However, it would be a good idea to use an amplified speaker such as those used for PC sound, as this would keep the load on the PFR audio amplifier to a minimum.

Also, since the PFR does not have AGC, be careful when using in the ear “ear bud” type headphones. Turn the volume control down when tuning across the band so that if you run across a strong station, it does not blow your ears off!

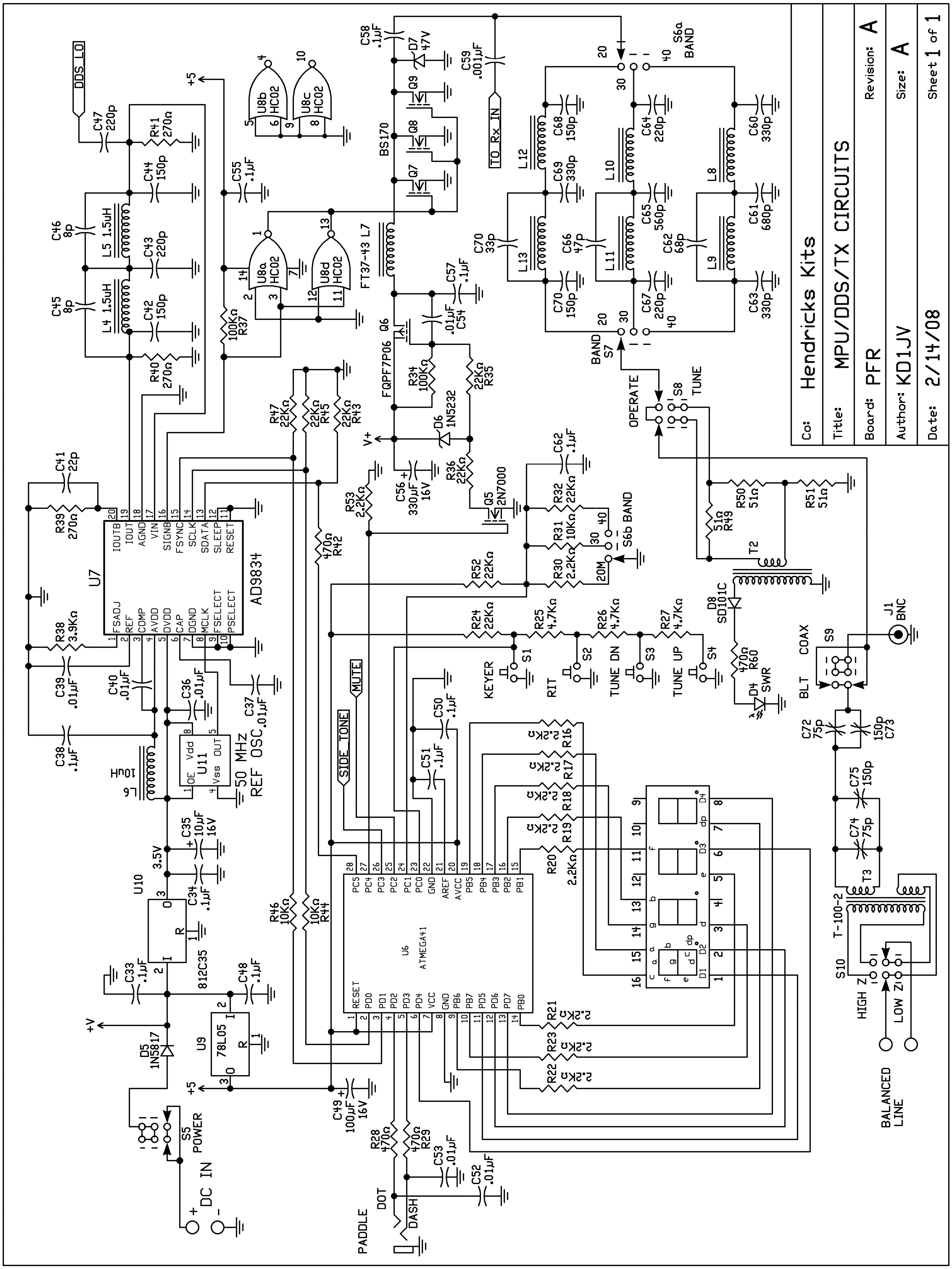
PFR front panel controls and rear panel connectors.



Schematics:
Receiver audio

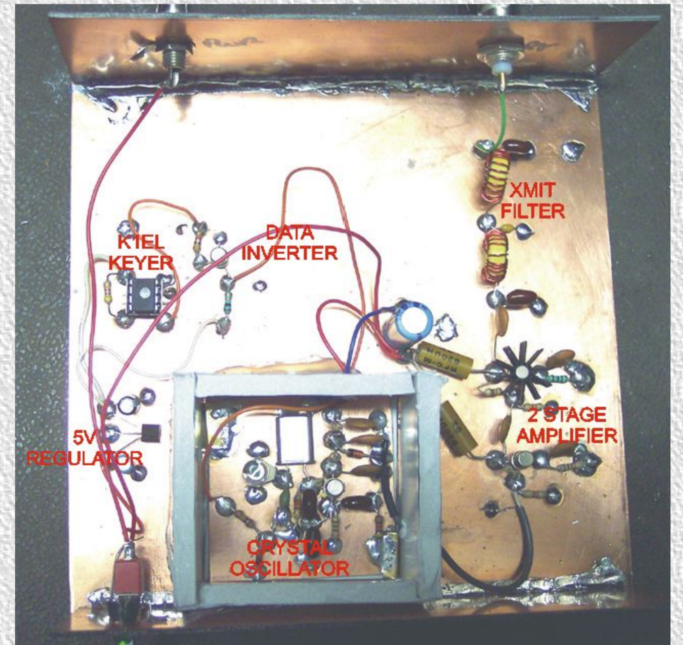


CPU, DDS, Tx



Co: Hendricks Kits
Title: MPU/DDS/TX CIRCUITS
Board: PFR
Author: KD1JV
Date: 2/14/08
Revision: A
Size: A
Sheet 1 of 1

The MODEL 1 MEPT Transmitter



This was my first attempt at building a QRSS Manned Experimental Propagation Transmitter (MEPT). It is a three transistor (2N2222) transmitter crystal controlled on 10.140Mhz. It has a power output of 50mW and a 5 Hz FSKCW signal with the top of the shift indicating the CW characters. The antenna is a 30 Meter Inverted Vee with the apex at 40 feet on my tower. It was turned on for the first time on Feb 18, 2009 at 00:21 UTC and was immediately spotted on the W8LIW Grabber. (reception reports are welcome at my email address). The schematic for this simple transmitter is HERE.

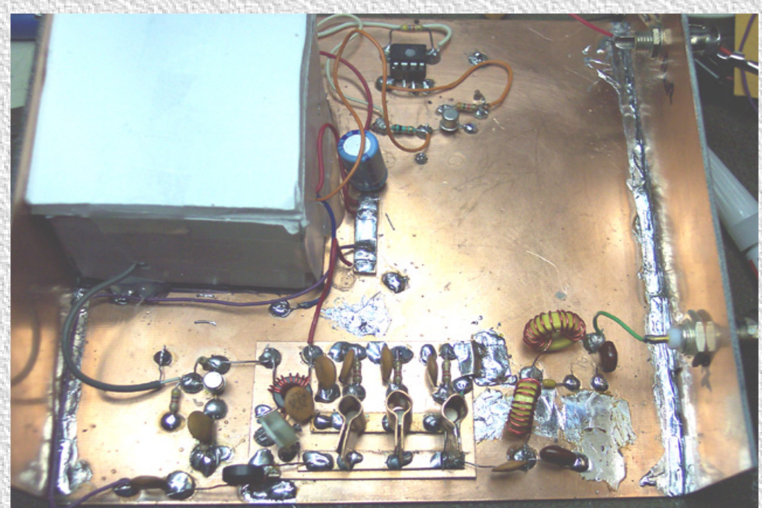
The circuit I used was from Radio Amateur 9H1LO Website along with G6AVK' website. I built it using the "manhattan style" of construction. The Oscillator section is mounted in a Foam box constructed from foam core display board to try to keep the temperature stable and the oscillator from drifting too badly.

The keyer chip was supplied from K1EL K-id and works very well. The keying ouput was opposite from what I wanted so a one transistor inverter was added to make the keying "right side up". I am presently using FSKCW keying at a 3 second dot rate. I may be changing this around to improve my DX rate. There is still much to learn about this mode of operation and study.

This was a really fun project. Now it will be very interesting to see where the reports come in from of the people who copy my signal.

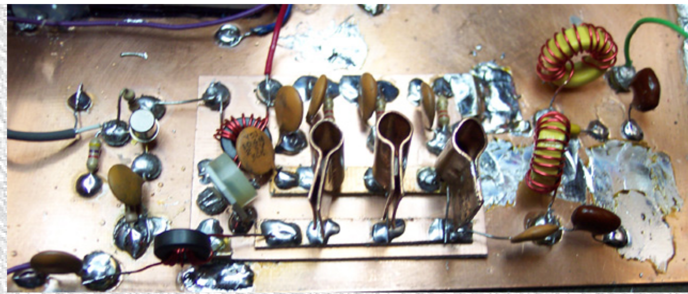
Further information will be posted as the project progresses.

FIRST MODIFICATION



Here is a little better view of the new final amplifier. You can compare it with the upper one to see how the layout has changed. We will operate this for a while and see how far I get or until it blows up. Right now it seems to be running cool and stable.

First Modification was to replace the single



2N2222 final amplifier with something that had a little more power. I chose the circuit used by K8IQY as used in his 2N2/40. It uses three 2N2222 transistors in parallel. It fit into my transmitter case with some minor moving of other parts of the circuit. I now put out 900 mW and hopefully, I will be seen in England, Belgium, or Australia. The white Pot on the left corner of the board allows me to adjust the power very smoothly from about 100mW to 900 mW. The homemade copper heatsinks will prevent early death of my transistors but at the present time they seem to be adequate.**

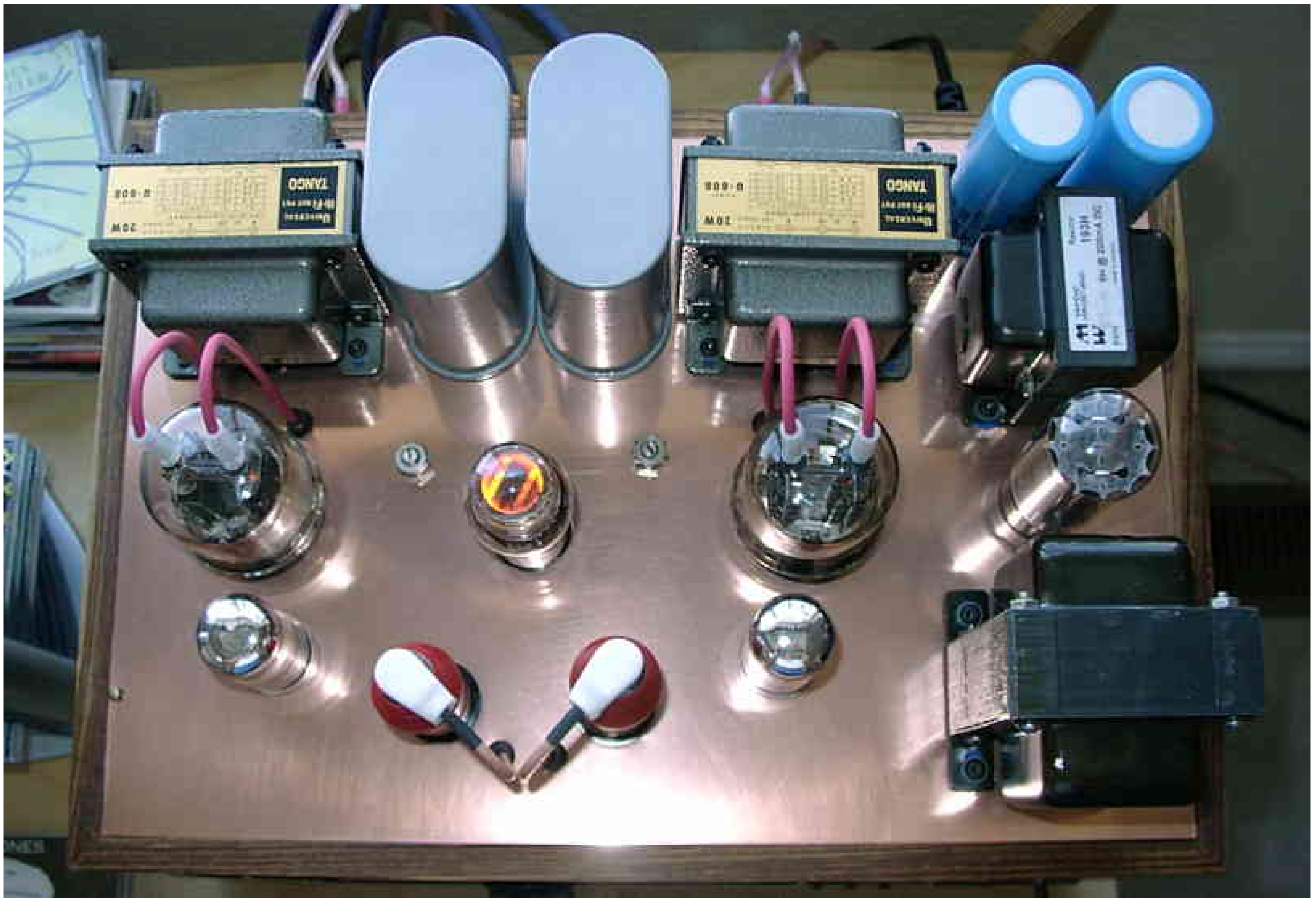
[back to MEPT Transmitter page]

[DIY Audio Home](#)

829B Triode-mode amplifier

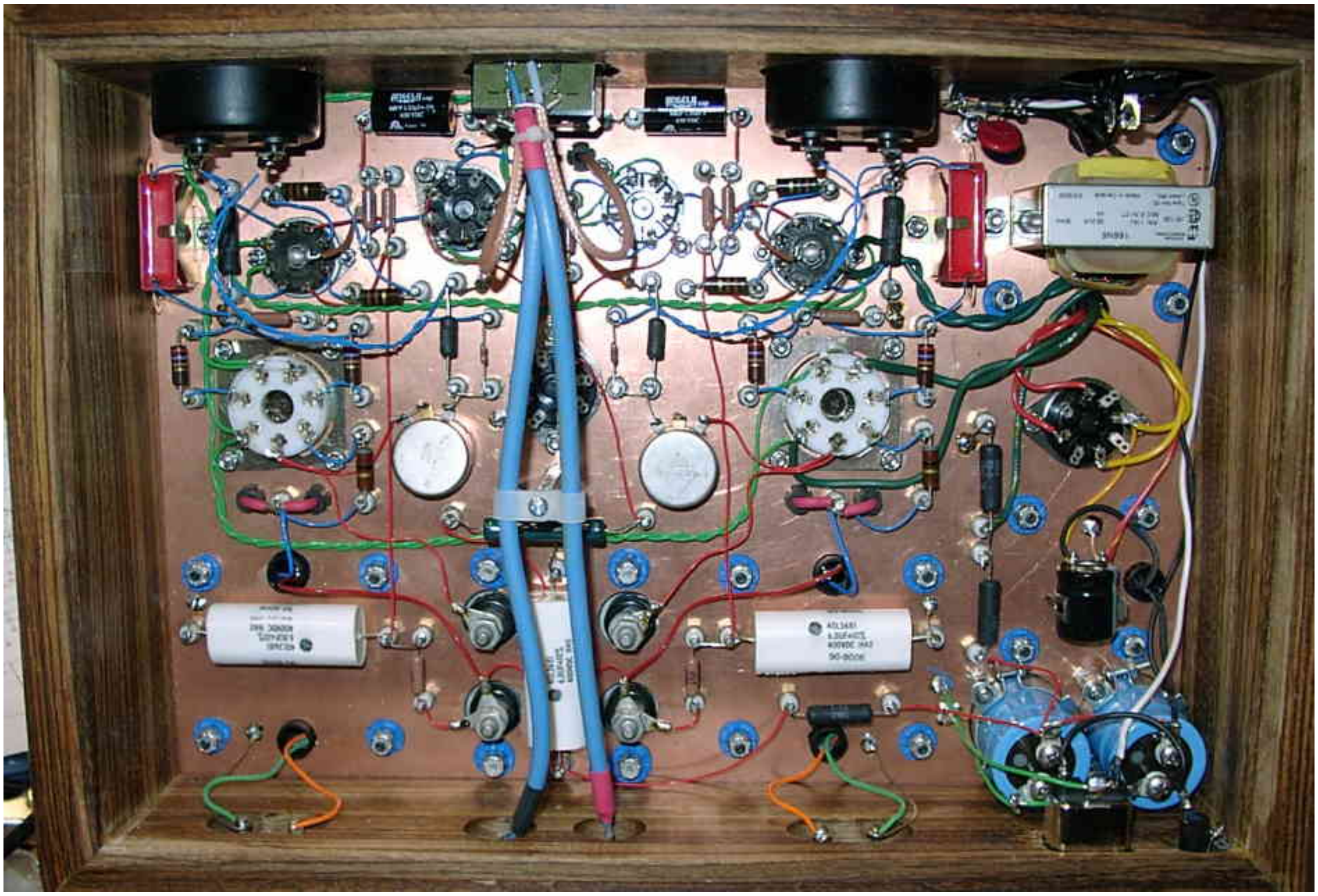
I've built a real stereo version of the 829B triode SE amp:

The base is made of Zebrawood, finished with oil - cost me about $50 for the wood but boy, it sure looks nice. The top plate is 0.029" copper sheet on top, with 0.062" PCB material underneath. The layering let me hide all the screws under the top plate, and the PCB material makes it easy to solder to a ground plane.



You can see the 829B's in front of the OPT's. In front of them are 7N7's (parallel-connected cathode followers), and in the front are a pair of EF37 pentodes, which are the input stage.

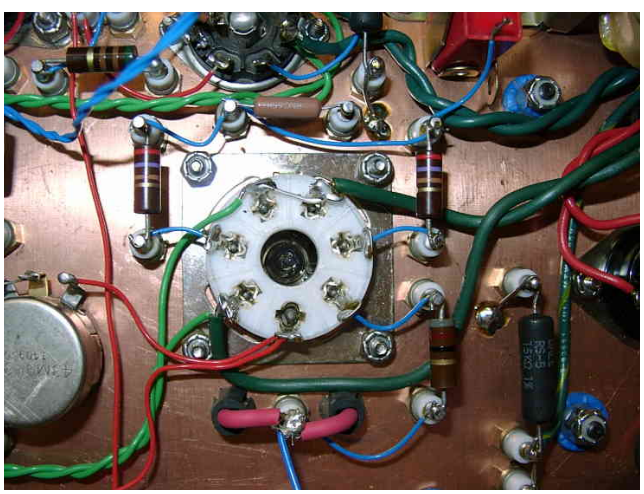
Here's a look at the inside:

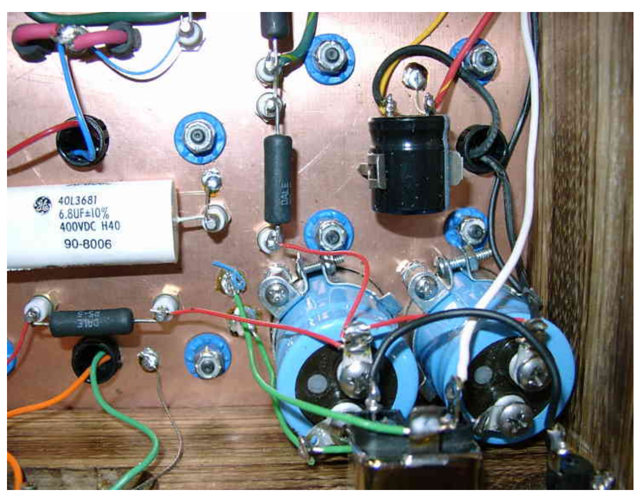


I used a different construction method than I have in the past - I used single-point terminals. I found some Teflon turret terminals at a local electronics joint for $0.30 each (Newark sells them for just over $5.00 each!), so I decided to use them here. You have to drill a lot of holes (about 75 in this amp), but it allows you to put parts exactly where you want them.

I also used the PCB as a ground plane. I'm sold on this method of construction, as opposed to trying to do wired star grounds. This is a lot easier and neater, and works very well.

Here are some more detail pictures (click on the photo for a larger version):





One thing I puzzled over for some time was how to connect to the 829B anode pins. It's hard to find anything that will fit them, and what I could find was uninsulated. I came up with a simple solution: I removed the "guts" from a euro-style terminal block, put set screws in it, and covered it with silicone tubing to insulate it. I also used silicone test lead wire, so the insulation doesn't melt. All in all it worked well, at least at the

(relatively) low power dissipation that I'm running. The wires run just cool enough that you can touch them, so I think all is well.

I'm running the 829B's at about 80mA, B+ of 320V, with cathode bias. For details look at the schematic (below). I don't seem to get a lot of difference varying the bias from 60 to 100mA.

The amplifier is -3dB down at 18Hz (by design), and the HF response is excellent - 3dB down at over 70kHz. It clips at about 5 watts. It's incredibly quiet; I measured -70dB referenced to 1 watt, and if I cut off the 60/120Hz, it's more like -80dB!

So how does it sound, you ask? I'm still letting it break in, but so far it's wonderful, better than it has the right to be for so little money (I bought 6 829B's, 4 RCA's and two Mullards, for a total of about what a single Sovtek 2A3 would cost). Very natural sounding.

The bass of this amp really surprised me. It is very clean and strong. Probably partly due to the output transformers, Tango U808's, and the very low impedance power supply (mongo capacitors).

The driver circuit performs very well. It clips at about 50V RMS (+/- 70V). The 829B only needs +/- 22V, so it has plenty of headroom.

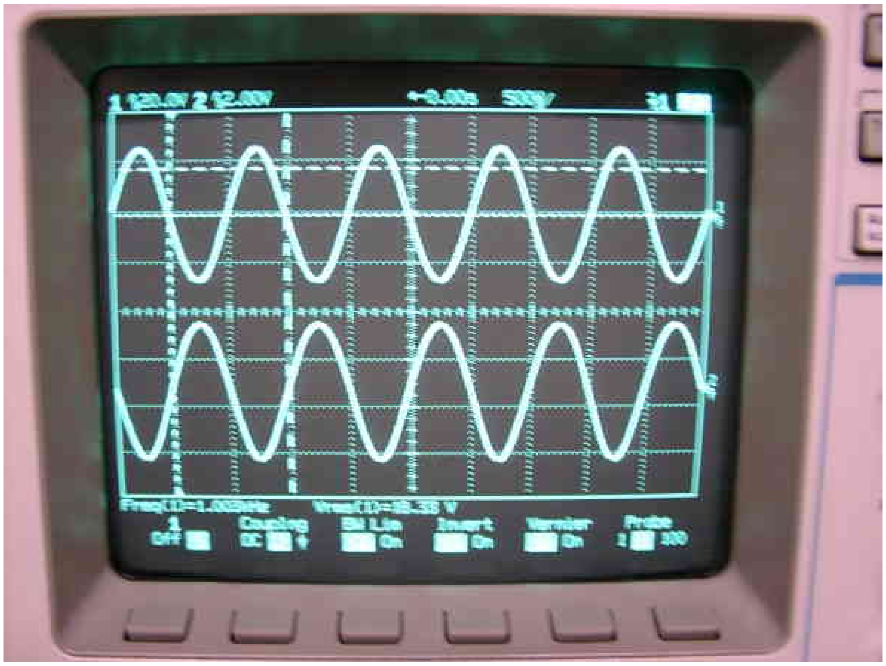
Here is the [full schematic]of the power supply and amplifier, as built (45kB PDF file).

Also, if you're interested in building something like this, I did some AutoCAD work and generated a [mechanical drawing] (113kB PDF file) and a [parts layout] (138kB PDF file) (as viewed from the inside). If you have OrCad and/or AutoCAD and would like the source files for any of these, email me at:

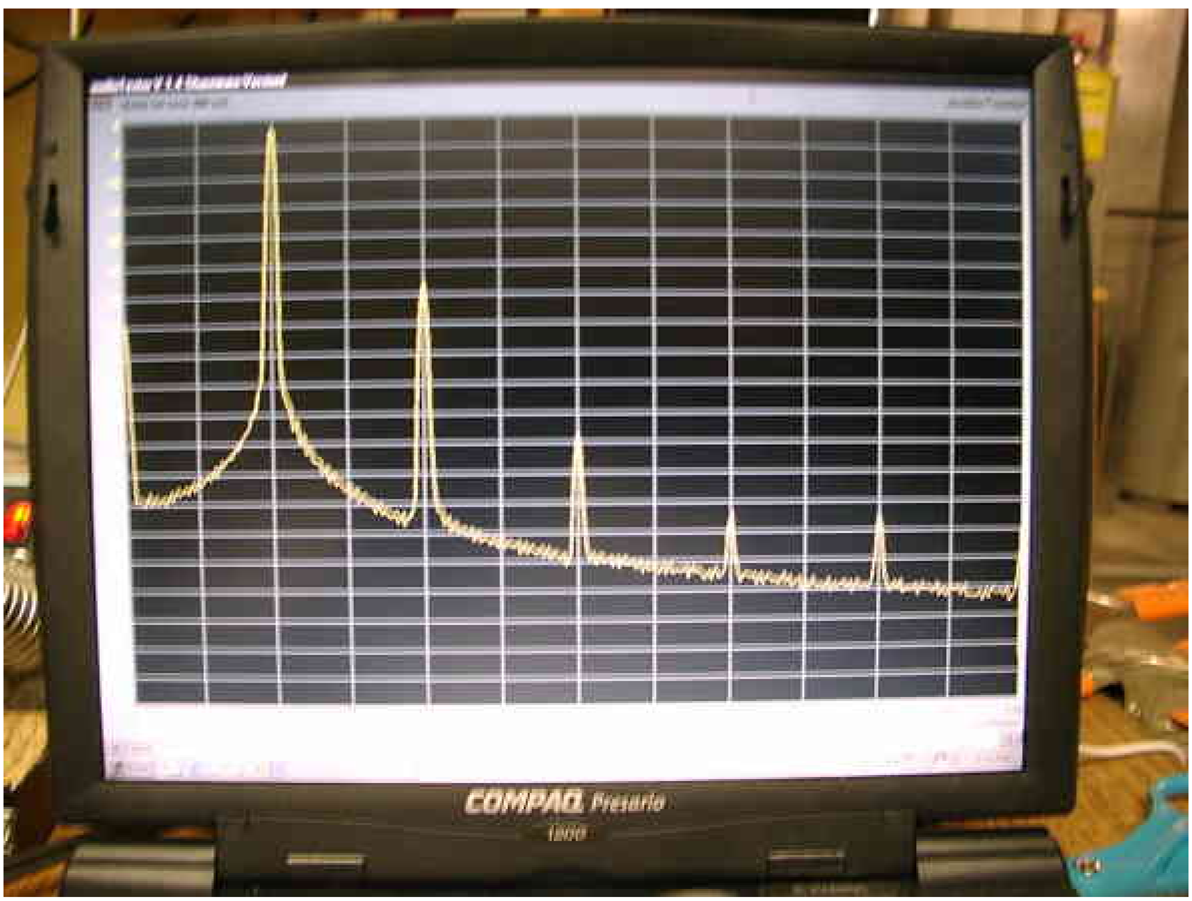
pete@pmillett.com

Here is some data I took while the amp was on a breadboard:

Here's a scope shot of the driver output (upper trace) and amp output (lower trace) at 5.3V RMS out into 8 ohms (about 3.5W):



I know it's hard to see, but there is about 4% THD on the output, mostly second harmonic. I hooked up my laptop and ran a spectral analysis, which looked very nice - mostly second harmonic, with progressively lower amounts of the next harmonics. Sorry for the lousy screen shot (with a camera - I need to get a Ethernet card for my laptop!)



This is not a low-distortion amp; even at 1W out, the THD is almost 1%. But the harmonic profile looks pretty good.

Frequency-Reconfigurable Microstrip Antenna for Software-Defined Radio

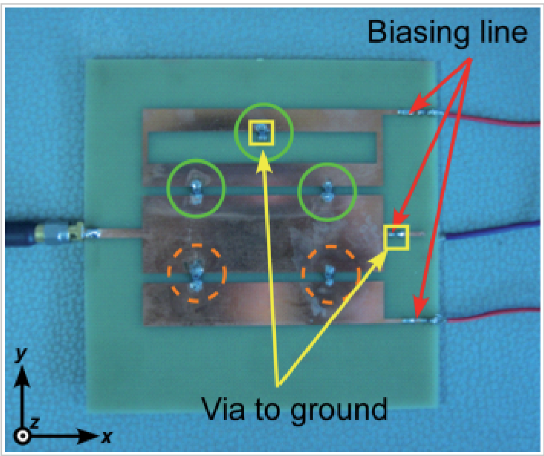


Fig. 1 - Frequency-Reconfigurable Microstrip Antenna for Software-Defined Radio

The increasing demand for portable devices with wireless connectivity within a wide frequency spectrum presents an ambitious challenge for the designer of the RF front-end who has to manage different wireless standards (GSM, UMTS, WiMAX, WiFi, Bluetooth, LTE). Covering several frequency bands simultaneously with a single antenna can be a very demanding task, which is why the employment of many different antennas integrated in the device and the use of multiband or broadband antennas might be a feasible solution for the problem. The use of different antennas implies an increase of the overall cost and space requirements. Broadband antennas transmit and receive signals within a large bandwidth but they may suffer an unbearable deterioration of the signal to noise ratio and thus a reduction of the overall efficiency of the system. Moreover, the electromagnetic spectrum is a shared resource that is more and more congested with the increasing number of users of wireless devices and the further exploitation of the available frequencies by other services poses practical and regulatory difficulties. To cope with this problem, the employment of an unused part of the spectrum or the opportunistic and temporary use of a shared portion may offer new resources.

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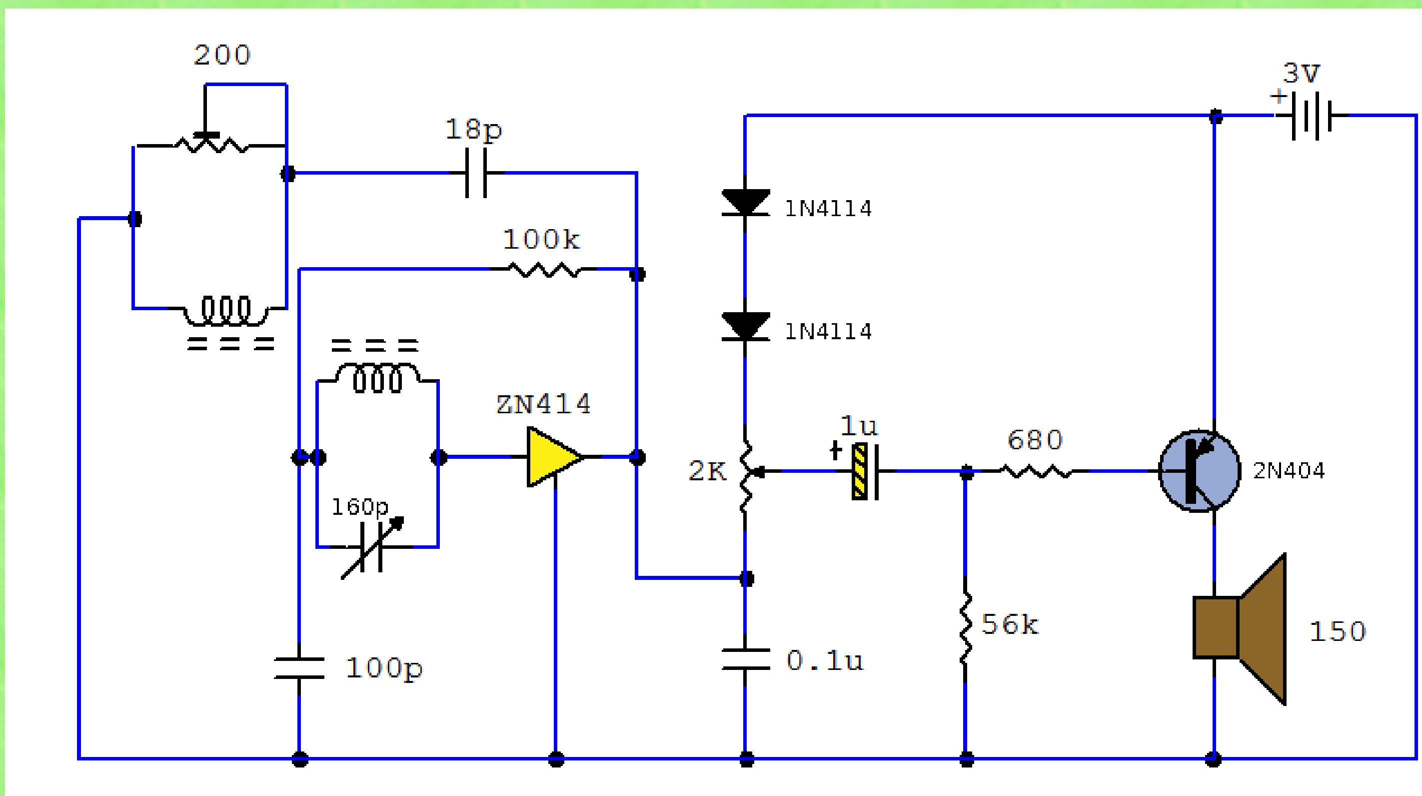
Ing. Simone Genovesi, Prof. Agostino Monorchio
Microwave and Radiation Lab., Dip. Ingegneria dell'Informazione
Università di Pisa

Circuit : Chad Castagana, Woodland Hills, CA
Email : chcastaga@aol.com

Description

A complete AM radio set based on the MK484 IC (formerly ZN414). It uses a PNP transistor and can drive a 150R loudspeaker.



Notes

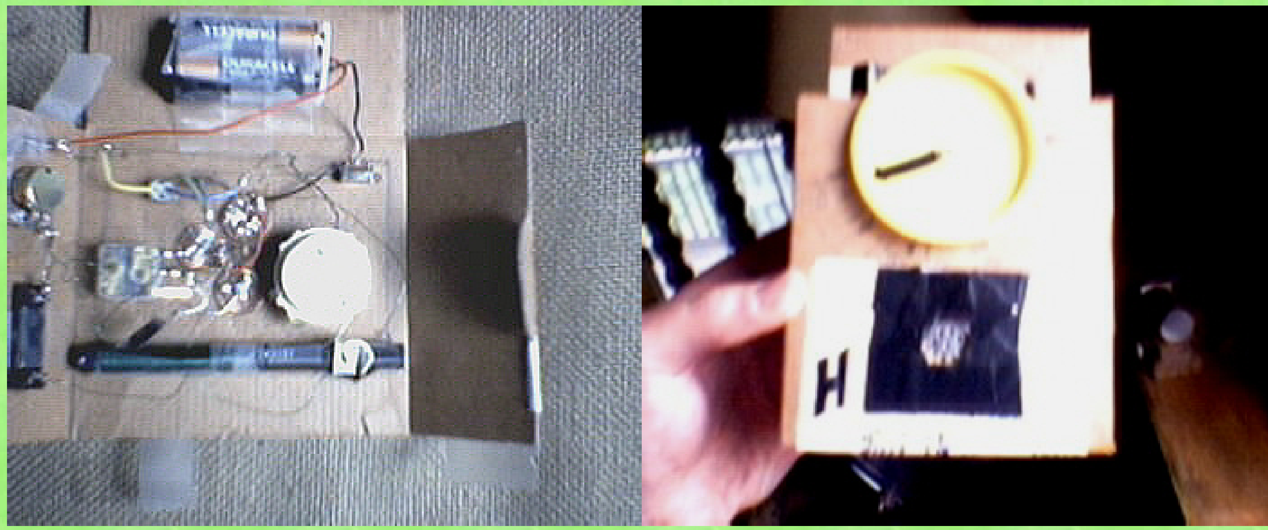
Chad has built a complete radio receiver using 1 IC and a single transistor. The IC requires around 1.2 to 1.6V and this is supplied via the 3V battery in series with 2 diodes 1N4114 diodes, (1N4004 can be substituted) and the 2k volume control.

Coil Details The Loopstick Coil is 2 7/8" in length and 6/16" in diameter. Tickler Coil is 6 turns and is spaced about one inch from primary coil. Primary coil is wound with 28 gauge enameled wire and the feedback coil is plastic insulated similar gauge. I do not know the permeability of the ferrite rod, I would guess it is 50 or so, for this is a

ferramic and not powdered iron. The small 18pf ceramic condenser that provides the feedback can be as high as 22pF or even 33pF.

Images

Chads finished receiver can be seen below.

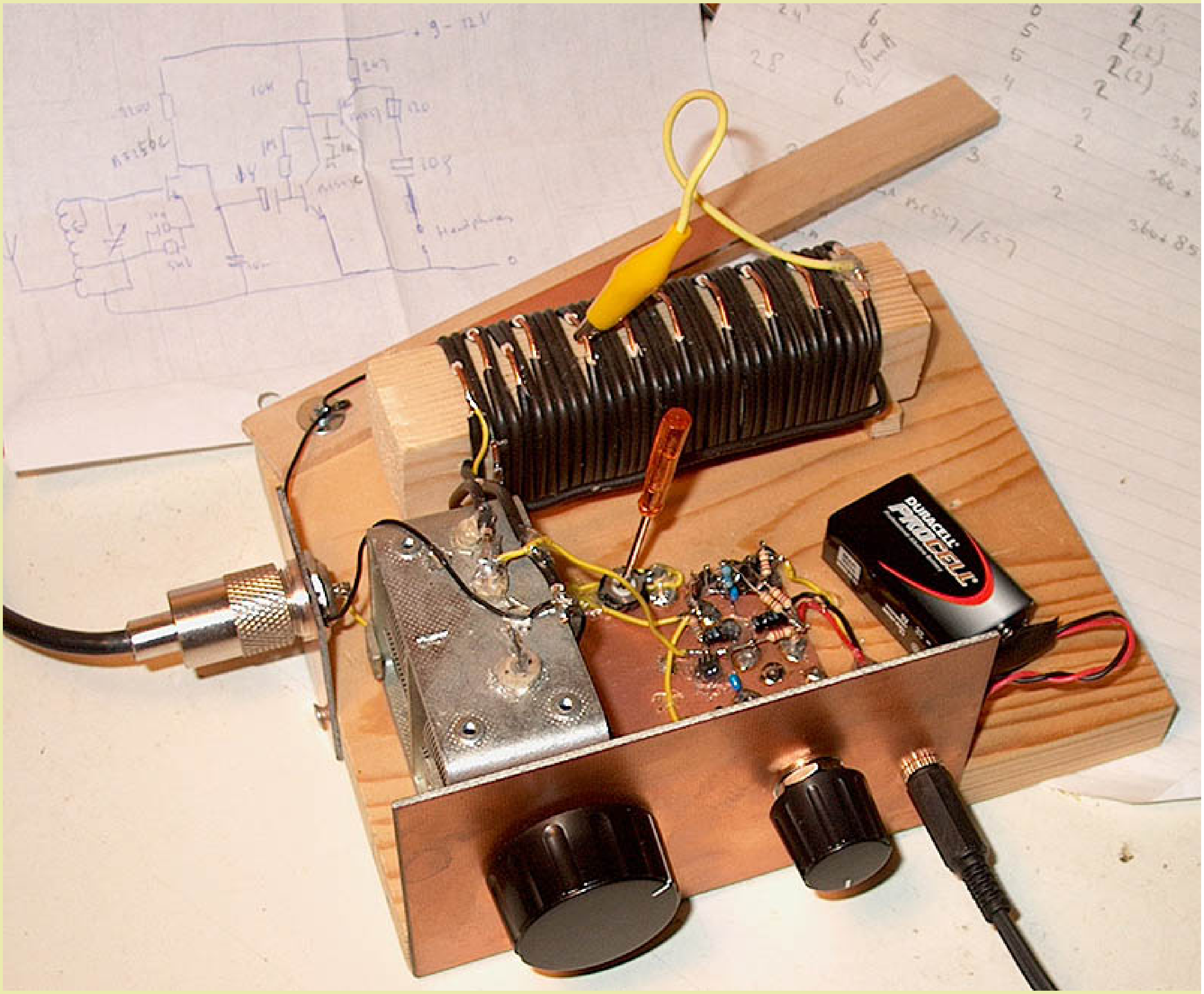


The audio output is amplified by a single 2N404 PNP germanium transistor and can directly drive a 150 ohm loudspeaker. The loudspeaker was purchased from "American Science and Surplus".

A GOOD REGENERATIVE RECEIVER WITH SIMPLE FINE TUNING

(2008)

KLIK HIER VOOR DE NEDERLANDSE VERSIE



A good SSB-CW-AM regenerative receiver with a fine tuning by moving the wooden stick with a grounded piece of PCB towards the coil.

A good regenerative receiver

When you add an LF stage and a fine tuning to the simple receiver with only one fet, you will have a much better regenerative receiver. No audio transformer is required anymore, the audio signal is much stronger and you do not need to use special, sensitive headphones anymore. By adding a simple fine tuning, tuning to SSB stations is not a problem at all, not even on the high 18MHz band, reception of that band is very good with this receiver!

Of course you cannot compare this receiver with a real good commercial receiver. But you can experiencef how it is to work with such a historical regenerative receiver. Controlling the receiver is very special. To adjust the feedback, continuously retune a little to correct the frequency drift, to adjust the RF attenuator. That was exactly how they did it in the past! And you will be astonisced about how much you can receive with it! On all bands from 1.8 MHz to 18 MHz,

many amateurs can be heard with a wire antenna of 5 meter! It is nice to play with it. To rotate the tuning knob slowly or very fast, and to be surpised about the strange signals that you will hear. Listening to remote broadcast stations and to be astonished about how strong these broadcast stations are compared with the signals of amateurs. With this receiver, you can receive the whole shortwave band upto 30 MHz, and even a part of the medium wave. But above 21 MHz, it does not work very good anymore, depending on the construction and the used fet, it might be that the receiver does not generate anymore at these high frequencies.

A simple and cheap construction

We want to make this receiver to experience how it was in the past, when radio operators had to work with such simple regenerative receivers. But we want to use easily obtainable parts and of course it should be cheap. Therefore, only one variable capacitor is used, it is also the only RF component that has to be bought. For the antenna coupling and the regeneration, potentiometers are used. And the fine tuning is also made without a variable capacitor.
This receiver is a nice home brew project. It is so simple, that the construction of it cannot go wrong.

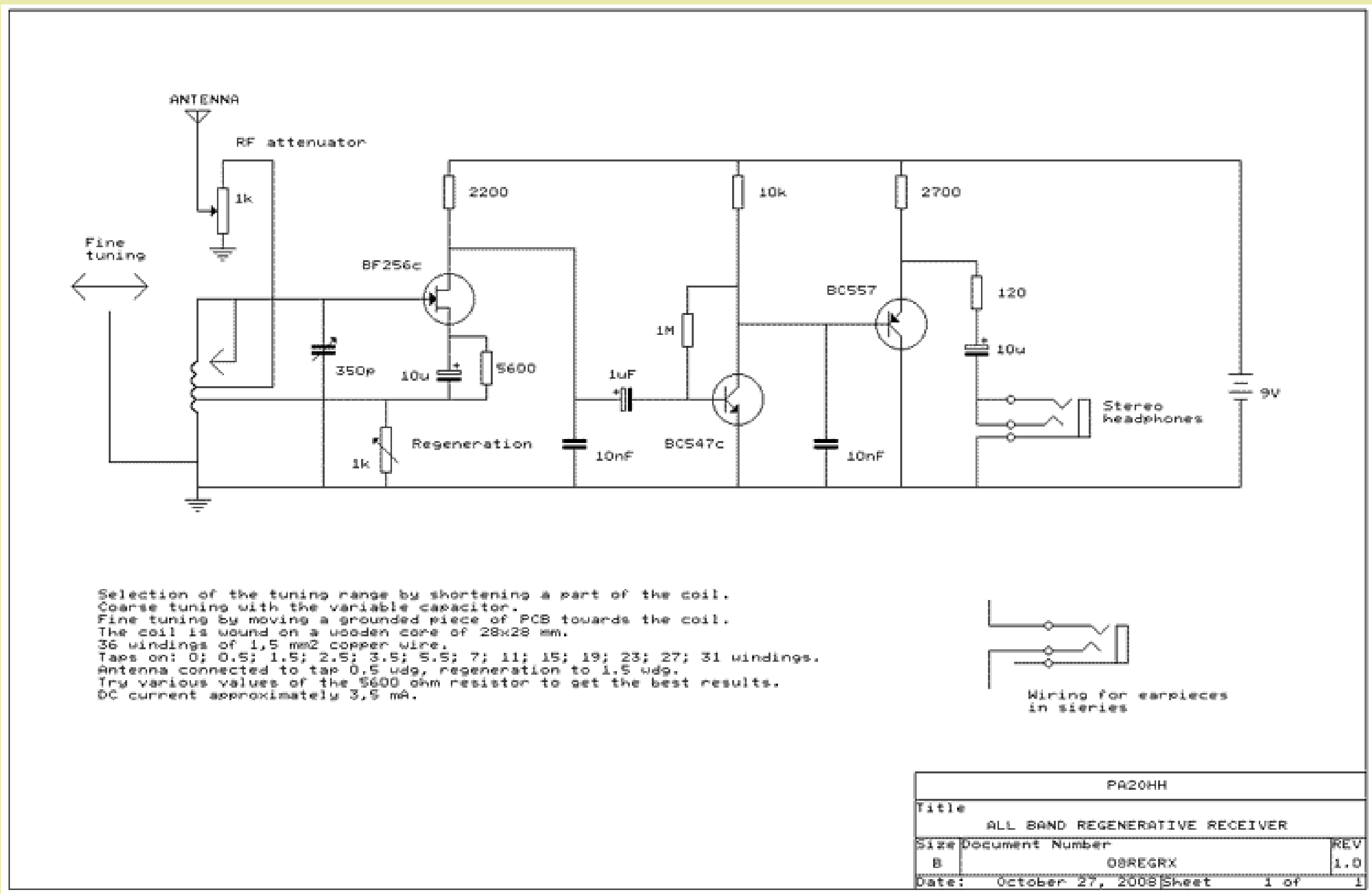
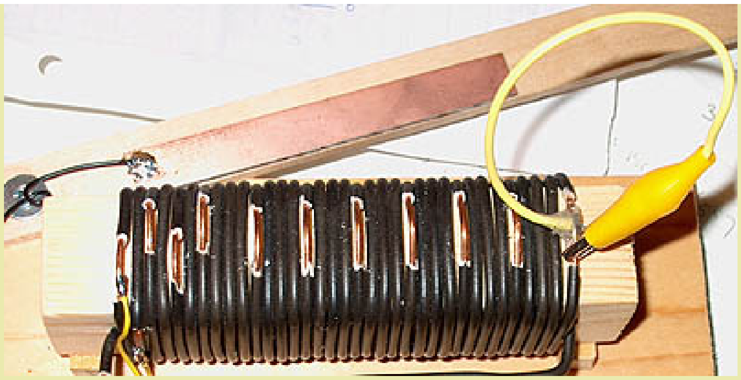


Diagram of the regenerative receiver.
big diagram

Description

The heart of the circuit is the fet BF256c (c type has the highest gain). By means of the 5600 ohm resistor, it works in the non- linear part of the Id/Vgs characteristic. Experiment with that value in your receiver for the best performance. The 10uF capacitor is for decoupling of the resistor, also for high frequencies. Perhaps that you need to add an extra 0.1uF capacitor in parallel for decoupling of the RF frequencies but I did not hear any difference. The regeneration is controlled by means of the 1k potentiometer. Adjust it for maximum sensitivity. In the original simple receiver, 10k was used, but 1k is a much better value.
A transistor BC547c amplifies the LF signal and the BC557 is the replacement of the audio transformer. It has a high impedance input and a low impedance output. Sensitivity and sound level are good. If you want more audio signal, then you can connect both pieces of the headphones in series! Quite often, the signals are too strong and then some RF attenuation is necessary. We can do that with the 1k adjustable potentiometer with a small screwdriver. Of course it is better to use a normal potentiometer with a knob at the frontpanel. This potentiometer is also the only volume control in the receiver.



The coil in use for 80 meter. for the other bands, a part of the coil is shortened.

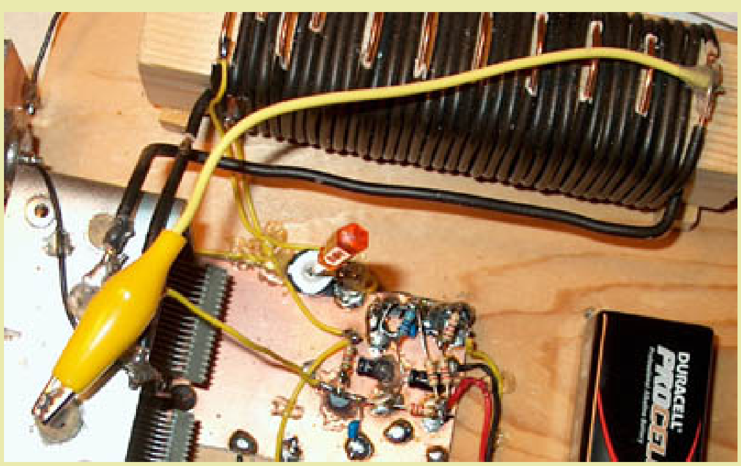
The coil

The coil is wound with 1,5mm solid copper wire (black) on a square strip of wood of 28x28 mm. The windings with a tap are pulled upwards a little and the isolation is removed. The short from the top are connected to these taps with a wire with a crocodile clip. I used a standard cord for that, but the wires are not soldered to the clip. SOLDER THIS WIRE AT THE BACK SIDE TO THE CLIP!! Otherwise you will have some contact resistance between the clip and the wire after a few years. The correct tap is determined experimentally. The receiver is very sensitive and it is not necessary to look for the best tap for the antenna and source. They are permanently connected to 0.5 windings and 1.5 windings. But for 10 meter, the antenna has to be connected to a lower tap. So it is better to have a switch for the selection of 2 taps for the antenna.

The coil in use for 20 and 30 meter.

Coarse tuning with the variable capacitor

Coarse tuning can be done with the variable capacitor. The various shortwave bands are selected by shortening a part of the coil. And 160 meter is selected by adding a capacitor in parallel to the coil. I use the second part for the variable capacitor for that purpose.

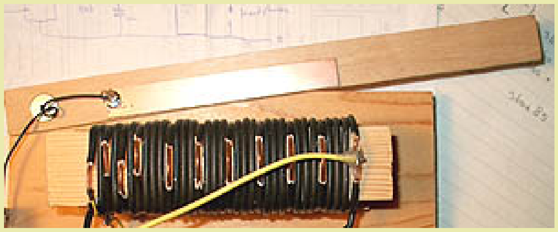


The coil in use for 160 meter. An extra capacitor is added, I use the second part of the variable capacitor.

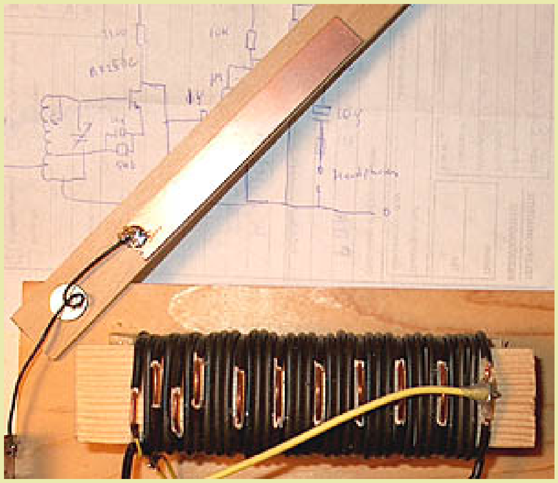
Fine tuning

The fine tuning by moving your hand towards the coil is quite tiring. But we have a simple solution for that. A wooden

stick with grounded piece of PCB that rotates around a screw. Drill a hole with the size of the screw in the stick and fix the screw with nut so that it moves smoothly. With this fine tuning, you can tune alsmost the whole CW or SSB part of the 40 meter band! You can change this frequency range by changing the size of the PCB.



Fine tuning with the stick with grounded piece of PCB.
It rotates around the screw with nut on the leftside.



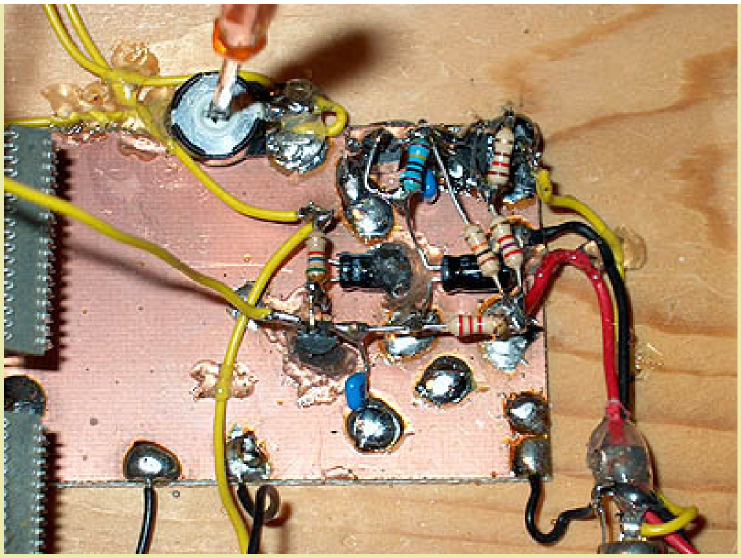
Close to the coil, the fine tuning works more coarse then when
it is far from the coil. This position is good for the higher bands.

Supply

The receiver works excellent with a supply voltage of 9 to 12 volts, supply current is approximately 3.5 mA. Reversing the battery did not damage the receiver. Perhaps that you need to connect an elco of 100uF across the plus and minus for certain batteries or power supplies. If you want, you can reduce the supply current with 1 mA to 2.5 mA by increasing the emittor resistor of the BC557 to 5600 ohm. Then the maximum audio power in the headpones is somewhat less, but in most cases still more than enough.

Results

The sensitivity is approximately 0.5 to 2 microvolts on all bands. S9 is 50 uV, S8 is 25 uV and so on.
In practice, that means that you can receive CW signals of S5 to S6, for SSB signals S6 tot S7. On all bands from 1.8 MHz to 18 MHz, many amateurs were received with SSB with a wire antenna of 5 meters length. The sound level is excellent.
Often, the RF attenuator has to be used (the 1k trimmer potentiometer with screwdriver). For the reception of broadcast stations, it is not necessary to connect an antenna, the coil and wiring do receive already enough signal.
Reception of AM broadcast stations is excellent when the receiver is oscillating very weak.When tuning to the AM station, the oscillating receiver synchronises to the carrier.
Of course you can change the receiver in accordance with you own ideas and wishes. It is for example possible to replace the variable tuning capacitor by a few switches with fixed capacitors of for example 200pF, 100pF, 50pF, 25pF that can be switched in parallel to a small (homebrew?) variable capacitor of 30 pF.
The fine tuning is excellent, it is a nice regenerative receiver, with which you can receive a major part of the shortwave and even a part of the medium wave band.



The simple small electronic circuit. Unbelievable, but you can receive the whole world with it!

Is this regenerative receiver a radio interference source?
When a regenerative receiver is oscillating, it can cause radio interference in the reception of other receivers. A part of the oscillator signal is transmitted via the antenna that is coupled to the regenerative detector. You can avoid this by adding a RF amplifier stage between the antenna and the regenerative detector. However, adding a broadband RF amplifier was not a succes, it was often overloaded by all kinds of strong signals. And a tuned RF amplifier was too complex for this simple receiver. Furthermore, we will not have the experiences as they had in the past, influences that antennas moving in the wind have on the reception frequency and regeneration.
But is this receiver really a terrible radio interference source? I do not think so, the oscillator power is at least already 100x lower than that of a tube receiver... I had the possibility to do some measurements. Between 1.8 MHz and 7 MHz, the emission was approximately -30 dBm (1 microwatt). Between 10 MHz and 24 MHz the emission was -25 tot -20 dBm (3 to 10 microwatt) and on 28 MHz again approximately -30 dBm (1 microwatt). That is not much, and it is only 1 signal on 1 frequency. And that frequency is your own reception frequency. So you can hear what you will disturb. When listening to SSB stations, your oscillator signal is exactly on the frequency of the suppressed carrier and will not cause any inconvenience.
The possibility that someone in your neighbourhood listens to the shortwave band is very small. And endless smaller is the chance that he is listening on the frequency of your regenerative receiver. So the chance that you will cause radio interference is almost zero!

My frequency scale
The next table is used as a scale to tune to the various bands.
The 5.3 MHz band is an amateurband that is used in the UK. The bands can be recognized by the many CW signals that you can hear at the lower ends of the amateur bands. Just above the 40 meter band and just below the 30 meter band, there is a broadcast band with many broadcast stations. Also nice useable signals to find the amateur bands.

Band MHz	Antenna tap	Source tap	Top tap	Tuning (degrees)	Sensitivity
1.8	1 (0.5wdg)	2 (1.5wdg)	12 (35wdg) + extra Cap.	160	4 uV
3.6	1 (0.5wdg)	2 (1.5wdg)	12 (35wdg)	260	2 uV
5.3	1 (0.5wdg)	2 (1.5wdg)	12 (35wdg)	360+10	2 uV
7	1 (0.5wdg)	2 (1.5wdg)	8 (19wdg)	350	1 uV
10.1	1 (0.5wdg)	2 (1.5wdg)	6 (11wdg)	360	0.5 uV
14	1 (0.5wdg)	2 (1.5wdg)	6 (11wdg)	360+95	0.5 uV
18	1 (0.5wdg)	2 (1.5wdg)	5 (7wdg)	360+90	0.5 uV

21	1 (0.5wdg)	2 (1.5wdg)	5 (7wdg)	360+150	0.5 uV
24.9	1 (0.5wdg)	2 (1.5wdg)	4 (4.5wdg)	360+135	1 uV
28	0 (0.1wdg)	2 (1.5wdg)	3 (2.5wdg)	360+85	2 uV

BACK TO INDEX PA2OHH

du1vss home brews

All about ham radio. Although some of my projects involved transmitters, rf amplifiers and antennas that operates outside the ham band, these things were solely for educational purpose only and experimentation.

Saturday, May 31, 2014

100W Dummy Load

A 100W quick and easy rf dummy load using a 100W 50ohm Caddock thick film power resistor. The large aluminum heatsink was bought at Rox Electronics. The dummy load was tested at 144MHz exhibiting an swr of 1:1.0 at 150W of rf power. ---73 de du1vss

Posted by hevirred at 2:45 PM

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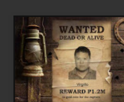


hevirred

Ham since 2000.

View my complete profile

K63 ONE-CHIP AM RADIO

This project presents the building blocks of modern day mini-sized AM radio receivers as found in key-rings, watches & palm-sized radios. They are:

- the Tuned Radio Frequency (TRF) front end
- a single chip AM radio IC, and
- amplification of the audio signal into a speaker

All these components are presented on a single printed circuit board so you can build and experiment with your radio. We have built the Kit using standard passive components. Commercial products usually use surface mount components which results in very small sized radios.

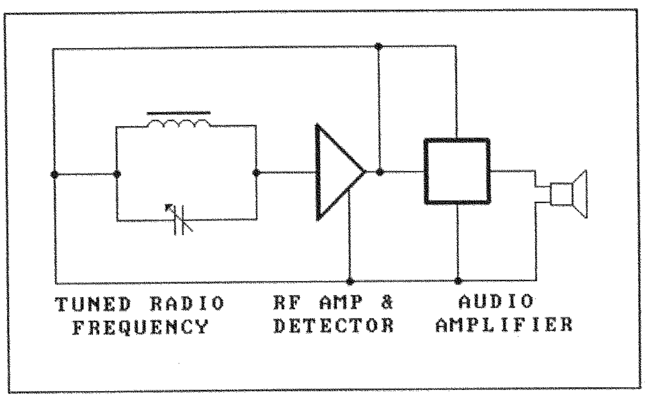
AM radio broadcasts consist of a radio frequency (RF) signal generated at a specific frequency allocated to a particular station. On this RF signal is superimposed an audio frequency signal. The audio frequency is said to amplitude modulate the radio frequency carrier.

AM RF signals of all frequencies are present all around us. Our radio must be able to be 'find' the station we want from all the thousands of signals present. It has to be able to tune into the desired radio station and exclude all other signals. And it must be able to tune into weak signals just as easily as tune into strong signals. Let us introduce two technical terms to describe these requirements.

Sensitivity is the ability to pick up weak signals while keeping the background noise to a minimum. **Selectivity** is the ability of a radio to tune into a particular station and reject all other stations. For mini-radio users selectivity is usually the more important: teenagers listening to heavy metal, adults listening to the horse races, soap operas and the news. Most often the listener wants to be able to pick up all the local stations without any interference even though adjacent stations may be very close on the dial. Usually they are not much concerned with being able to detect distant AM signals say over 30 miles away.

1. The TRF Front End

This consists of two components, the ferrite aerial coil and the tuning capacitor. The important word is tuned. All the AM signals reaching the radio are very, very weak. Only that signal which matches the TRF frequency is magnified by resonance so that it stands out at a very much higher level of signal strength.



This Kit uses a standard 60/160 AM Tuning Capacitor. It contains two film capacitors. Their capacitance changes as you turn the knob. We only use the 0 - 160pF capacitor for our radio. (The other 0 - 60pF capacitor is used in better quality AM radios that use regeneration on the aerial coil.) The centre pin is the common connection. The two screws on the back of the package are to trimmer capacitors associated with each capacitor. If you are unfamiliar with this item connect it to a capacitance meter and play with the main adjustment knob and the trimmer capacitors so you understand what is happening. In this radio the position of the trimmers does not matter.

The second component of the TRF is the coil & ferrite bar. We supply the coil prewound with 90 turns of 3 strand Litz wire. We got these coils from a commercial manufacturer of these coils who supplies exactly the same item to AM radio manufacturers. Litz wire consists of many strands of fine enamelled wire twisted together with cotton to add strength. Litz wire has a significantly lower resistance to RF than a single wire and is used in virtually all commercial coils.

The ferrite bar increases the inductance of the coil. The two components connected in parallel form a LC network. The Litz wire of the coil and the ferrite bar give the network a high Q, or Quality factor. This is critically important for the selectivity of the radio, the ability to tune into one radio station only and not be able to hear several others at the same time.

The coil winding & the ferrite bar acts as an efficient wire antenna. No additional external antenna is needed. The only disadvantage is that the tuned circuit is is directional. Signal strength depends on the orientation of the bar with respect to the origin of the signal.

2. AM Radio ICMK484

It is important to realise that the radio IC does not create any sounds by itself. It can only take the RF signal provided from the TRF circuit, amplify it, separate the audio signal from the RF (called detection) and pass the audio signal on to be amplified. It has no selective or rejection components contained in it. (This is in contrast to superhetrodyne receivers.) The MK484 we use is a Japanese copy of the original ZN414. It contains an RF amplifier, active detector and automatic gain control (AGC to improve sensitivity) all in a 3-pin package. The input impedence is typically 4M ohm. It operates over a range of 150kHz to 3MHz. DC supply of 1.1V to 1.8V & 0.3mA current drain makes it ideal for battery operation. The output is typically 40 - 60 mV of audio signal. Optimal AGC is provided by R3 and C2 (see Figure 2). R3 (the AGC resistor) should be in the range 100R to 1.5K. A bandwidth of about 4kHz is achieved. Download the MK484 data sheet from

K63 ONE-CHIP AM RADIO

http://kitsrus.com/projects/mk484.pdf

3. Audio Amplification
The audio signal output from the MK484 is too weak to drive a speaker directly. In our Kit the signal is fed into two stages of amplification and then into a speaker. These are standard designs. The first is a transistor Class A amplifier. The second is a Class AB amplifier. See DIY Kit 48 Introduction to Class AB Amplifiers for a description of how it works.

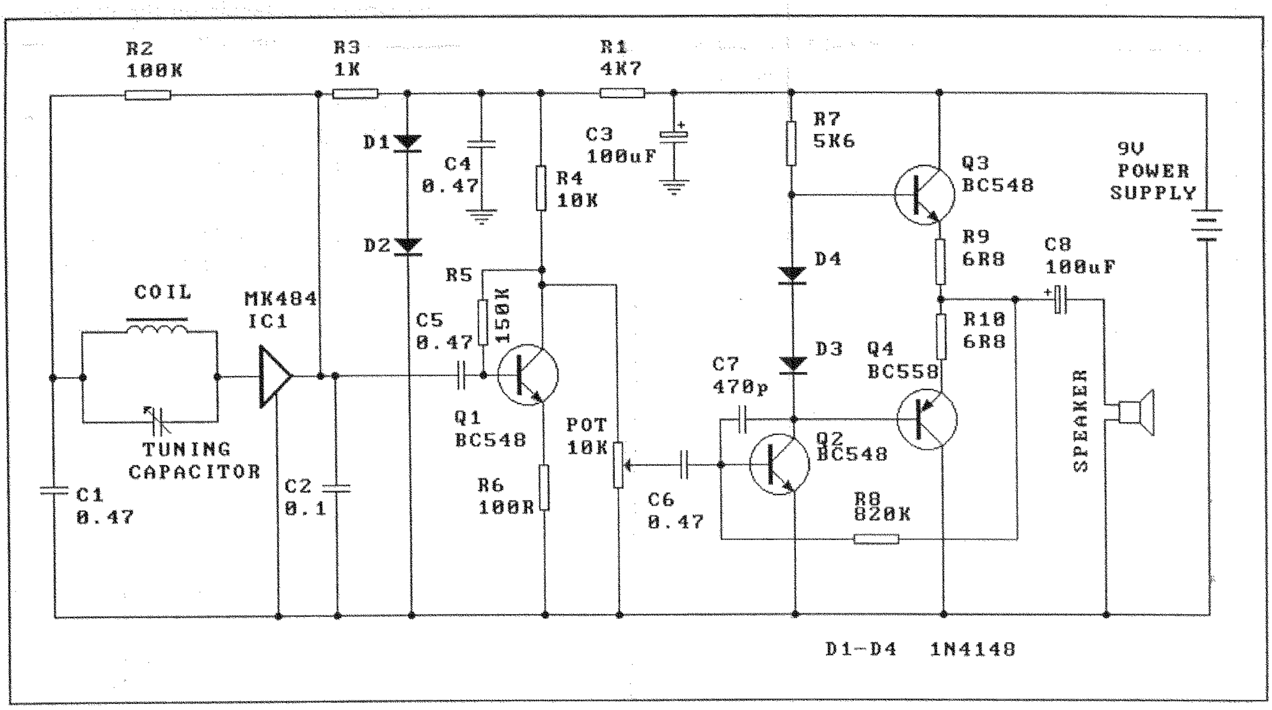
Our Design
Our circuit is show below. You should be able to understand most of it from the above block descriptions. The two forward biased diodes D1 & D2 appear to short circuit the power supply to the MK484, but this IC only requires about 1.5V to operate and the combined forward drop of the 2 diodes is exactly right. The tuning capacitor has been securely mounted on the PCB by 2 screws. We have provided an extension rod to fit onto the capacitor tuner so that a knob can be attached. The volume potentiometer is also mounted on the PCB. Mounting holes to tie down the aerial coil have also been provided. We aimed to provide the complete radio, excluding speaker, on a single PCB so that it was easy to experiment with. It can be modified to fit into a box.

Construction
Components may be added to the board in any order. But it is usually best to add the lowest height components first, the resistors and diodes. Make sure you get the diodes around the correct way. The black bar on the diode corresponds to the bar on the overlay. All the BC548, BC558 and the MK484 come in a TO-92 package. Identify each one and put them in their correct positions as shown on the overlay.

If It Does Not Work. Check that the diodes are all in the correctway. Are the resistors in the right places. Check that the TO-92 packaged components are in their correct places and orientation.

COMPONENTS

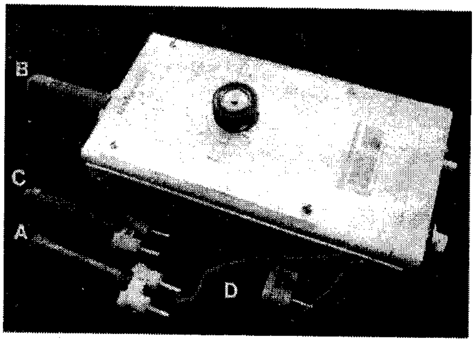
Resistors 1/4W, 5%, carbon:			
6R8	R9 R10	blue grey gold	2
100R	R6	brown black brown	1
1K	R3	brown black red	1
4K7	R1	yellow violet red	1
5K6	R7	green blue red	1
10K	R4	brown black orange	1
100K	R2	brown black yellow	1
150K	R5	brown green yellow	1
820K	R8	grey red yellow	1
10K log pot		Piher	1
Spindle for pot			1
Capacitors:			
470p ceramic	C7		1
470nF monoblock	C1 C4 C5 C6		4
100nF monoblock	C2		1
100uF elcap	C3 C8		2
60/160 AM tuning cap			1
1N4148 diode	D1 D2 D3 D4		4
BC548			3
BC558			1
Screws for tuning cap			2
Brass extension			1
Screw for extension			1
MK484 AM radio IC			1
2 pole terminal block			2
Coil & ferrite bar set			1
3", 0.5 or 1W, 8 ohm speaker			1
Kit 63 PCB			1
Documentation			



TINKERDIP-A HOMEBBREW BEGINNING

-Ranjan Chakrabarty

Amateur Radio has slowly emerged in India from a totally unknown hobby to a stage where it finds occasional space in literature devoted to the electronics hobbyist. Ham radio, as it is popularly known, is operated by two kinds of people worldwide: one who opt for readymade equipment and the others who prefer to build their own. It is the latter group that is severely handicapped in our country because of inadequate literature adaptable to local conditions. This article reveals that it is perfectly possible to make and operate amateur radio gear with little money and of course a large measure of zeal.



To operate an amateur radio successfully, it is necessary to make measurements at all stages. With a home-built gear it is practically impossible to do without measurements at all stages from start till the finished piece of equipment reaches the operating table.

Though quite crude methods often suffice, one must appreciate that the more refined the measuring instruments and methods, the more information can be obtained. Hence a piece of equipment can be adjusted for optimum performance more quickly and surely. " The regulations governing amateur radio operations require that the transmitted serial be maintained within the limits of the bands of frequencies allotted to the service. Consequently, it is imperative that homebrew gear be built to abide by such regulations. For the homebrewer, a dip meter is one of the most useful instruments to possess. Fortunately, it is also one of the (comparatively) easier projects to start with.

The instrument The 'Tinkerdip' is a solidstate FET GDO./Wave meter (acronym for Gate Dip Oscillator) calibrated to operate from 4.9 MHz to 88 MHz in four ranges. The circuit is based on data published in several amateur radio journals and is not original. However the entire approach has been to enable the use of locally available components and therefore suitable modifications have been made as shown in Fig. 1. These include the addition of a DC amplifier and the ability of the instrument is doubled as a sensitive wave meter. The reason it is called the Tinkerdip is personal and arose from the fact that all homebrewing involves a lot of tinkering. The 'tinker' series of homebrew gear started a long while ago in my ham radio career, graduating from simple code practice oscillators to fully solidstate SSB generators and frequency counters etc.

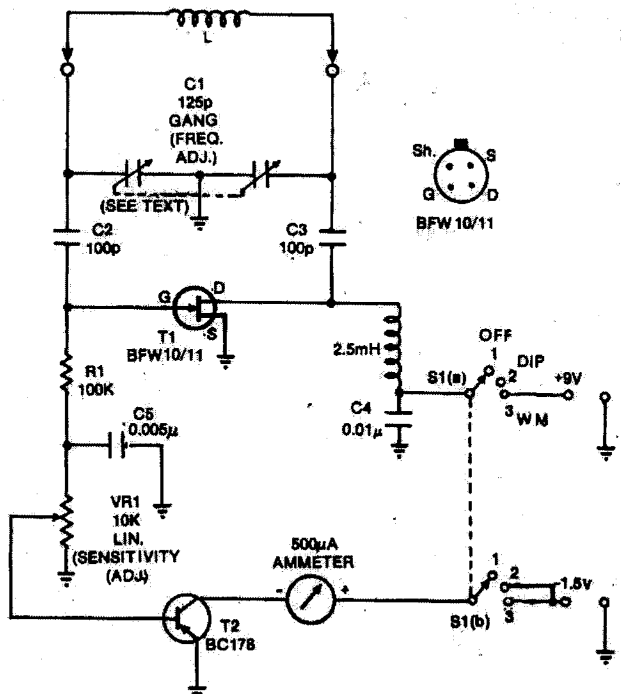
Principle of operation

One must understand that a meter is simply a stable calibrated oscillator operating over a desired range, to which a meter has been added to indicate the amount of bias current (gate current). When the oscillator is coupled to a tuned circuit and tuned through resonance with it, the meter will indicate a fall or 'DIP' in gate current. The reason is the unknown external circuit which absorbs energy from the oscillator when both are tuned to the same frequency, resulting in decreased feed-back in the oscillator and a consequent drop in gate current. If the unknown circuit has a reasonably high 'Q', the dip is quite pronounced. The circuit to be tested need not be energised. Obviously, a GDO can be useful only if it is compact and can be easily coupled to circuits under test. The Tinkerdip was thus conceived along1he following lines:

1. Must be conveniently hand-held.
2. Must have a wide tuning range.
3. Must have a direct reading calibration.
4. Must have a neat professional appearance.

Construction

Considering these conditions the AUGUST 1987 Tinkerdip was made in an aluminium box measuring 5x8.5x16 cms (HWD), fashioned entirely at home from a 18 SWG sheet: A thicker gauge and any other material is difficult to work with while a thinner gauge neither lends the desired strength nor can be tapped for machine screws. In case a similar readymade box is available, use it by all means since that saves a lot of sweat. The box is composed of two 'U' sections, the electronics being assembled in the broader 'U' while the other is used as the bottom/side cover.



L—15mm (OUTER DIAMETER) PHENOLIC FORMERS/26 SWG ENAMELLED COPPER WIRE
A—71 TURNS
B—20 TURNS
C—8 TURNS
D—1¼ TURNS 17mm (INNER DIAMETER) AIR CORE/18 SWG ENAMELLED COPPER WIRE
S1—2-POLE, 3-WAY MINIATURE SLIDE SWITCH

The plug-in coil forms are made from quality IV antenna connectors(male) and phenolic formers. The latter, cut to 6cm lengths, are notched at one end to accommodate the connector, force fit and epoxied to the former. Ceramic connectors, if available,should certainly be used instead.

The calibrated dial is made from 3mm thick 10.5 x7.5 cms Perspex sheet, requiring careful working with hand tools. A little carelessness can easily result in unsightly scratches, marring the looks of an otherwise well made instrument; The actual calibrations are written carefully with a drawing pen on snow white bond paper, cut to size and held in place by the perspex sheet that a~ts as a protective cover. The pointer is made from a 1cm wide strip of perspex
epoxied to the bottom of a small knob. While doing this, it is wise to check that with the capacitor fully meshed, the hairline on the pointer aligns with the calibration.

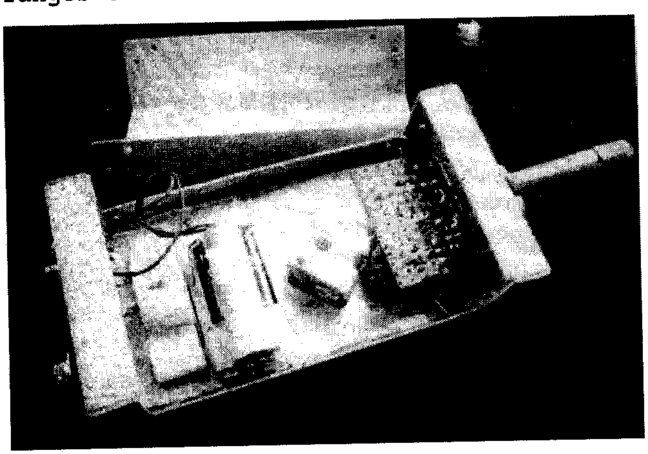
The TV antenna connector that acts " as the socket for the plug-in coils is mounted on the top lip of the U chassis. Since not much circuitry is involved, no PCB pattern was made; the components were mounted on a piece of veroboard, which was then mounted across the lugs of the TV connector and those of the variable capacitor. Sufficient mechanical rigidity is thus achieved. All RF wiring is kept as short as possible.

A small edgewise meter (500u AFSD) used to indicate the gate current via the PC amplifier is epoxied with thermocole brackets to a slot that clears the meter face. Enough space is left for the battery power sources (9V and 1.5V). The sensitivity control (VR1) and the Off/Dip/WM switch are mounted on the bottom lip of the U chassis. 3mm and 6mm brass machine screws are used throughout as standard fasteners and the chassis is tapped wherever necessary to accept them. The complete chassis is painted pale-green and the controls labelled with dry transfers.

The electronics

The colpitts oscillator is simple, requires a minimum number of components and is exceptionally stable when carefully made. The 125pF split stator variable is not critical and can easily be substituted. Decreasing or increasing the value of capacitance will directly lead" to a slower or faster tuning rate respectively. A capacitor with a large value can easily be tailored; the thumb rule is to divide the total capacitance per section by the number of rotor plates (in that section) to obtain the capacitance per plate. One now has only to remove the number of plates required to obtain the desired value. In the interest of stability, always pick a double bearing capacitor. A 500A FSD meter was used because it was readily available; any other movement between 250uA and 1 mA is suitable. The most-inexpensive-kinds are the 'VU' meters used in hi-fi systems; they generally have a 500uA scale.

The coils are wound with a 26 SWG enamelled copper wire except coil 'D' which is made from 16 SWG stock. All the coils wound on formers are weatherproofed by dipping them in a solution of NC paint thinner and 'Quickfix (or any other epoxy based adhesive}. The novice homebrewer should keep in mind that changes in coil dimension! will alter inductance, thereby affection! the ranges covered.



Testing and calibration

Once the instrument is complete(and the batteries installed, it is ready fo preliminary check before calibration Plug in a coil, advance the sensitivity control by about one-forth of its full trajectory and then switch to the 'DIP' position. The meter should instantly register a gate current; grip the coil in the palm of your hand and a dip in gate current should be noticed. Once this has been achieved the 'Tinkerdip. Is ready for calibration.

It is ideal to have access to a digital frequency counter, but failing this, most ham rigs that are commercially made these days have a general coverage receiver going up to 30 MHz. Assuming that neither is available with the builder, the easiest place to locate them is the nearest engineering college and the nearest radio ham who operates a commercial rig (in that order).

To calibrate the dip meter, switch it on to the 'DIP' position with a coil plugged in and sweep it through its range till a tone is heard on the receiver. Once a tone is heard, sweep it to the maximum capacitance (lowest frequency) position and then mark the g dial at 1 MHz intervals, noting that at the exact 1

MHz points, the tone heard from the receiver decreases in pitch from a high to a low to zero beat. All d four coils may thus be calibrated, provided the receiver tuning covers the entire range.

When using a counter, the moment the test signal is fed into the entry port a readout is available on the display. Use as loose a coupling as possible that permits a legitimate display; overloading the entry port will give false readings.

Usage

The dip meter is normally used to measure the resonant frequencies of unknown LC circuits but may also e used otherwise. It can be used as a variable signal source where the degree of coupling wIIl vary the desired signal e level. With a standard L and C, unknown values of C and L can be found respectively. It may also be used as a quartz crystal activity checker by plugging in the crystal in place of the it coil; the amount of deflection indicating the strength of oscillation.

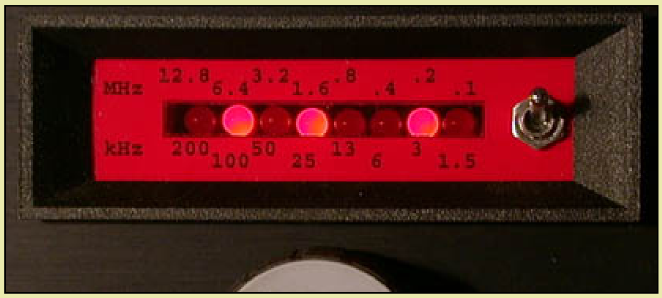
In conclusion, it would be a betrayal of the legacy handed down by radio hams of yesteryears when homebrewing was the rule rather than the exception, if we cease to continue. I would it like to thank VU2EM (Avinash Missra, my guru), VU2ATN, VU2DB, VU2LL, VU2PB, VU2ALP and VU2TKS, who have all been my major source of inspiration and encouragement over the years making possible more than a decade's operation of ham radio with a 100 per cent homebrew a station.

(Reproduced from Electronics For You, AUGUST 1987)
-Scanning & OCR at VU2MUE

SIMPLE FREQUENCY COUNTER WITH 8 LEDS DISPLAY

(1997)

NEDERLANDS ARTIKEL BENELUX QRP CLUB



Why simple?
What I wanted was a frequency counter for QRP use, so that I do not have to make an analogue dial and always have a correct frequency read out. An extra advantage is that after making some modifications to the VFO it is not necessary to make a new frequency scale.
But....
I did not like the idea of adding a frequency counter to my QRP transceivers that was more complex and draws more current than the transceiver itself. So the counter should be simple, easy to build, small display and circuit, low cost, low current consumption but it was not necessary to have a perfect counter.
Well, this design is the result.

The display
The idea was to have a binary display with 8 leds. The frequency can be found by adding the frequency values of the illuminated leds. The frequencies of the leds D7 to D0 are:

200 kHz - 100 kHz - 50 kHz - 25 kHz - 12.5 kHz - 6.25 kHz - 3.125 kHz - 1.5625 kHz.

As this is a little difficult to add, the figures are rounded off to the following values:

200 kHz - 100 kHz - 50 kHz - 25 kHz - 13 kHz - 6 kHz - 3 kHz - 1.5 kHz.

Example: Leds D7, D5, D3 and D0 are on: 200 + 50 + 13+1.5 = 264.5 kHz.
However, we want to measure frequencies that are higher than 400 kHz. Therefore, a switch is added so that the led frequencies are higher if the switch is in the MHz position:

12.8 MHz - 6.4 MHz - 3.2 MHz - 1.6 MHz - 0.8 MHz - 0.4 MHz - 0.2 MHz - 0.1 MHz.

But mostly you do not need the switch. If you have for example a QRP transceiver for 10.1 to 10.15 MHz then you do use only the kHz position and you can see that you have to add 10 MHz to the kHz frequencies:
If you read 138 kHz (led D6, D4, D3 on) it is 10 MHz + 138 kHz = 10.138MHz.
Ok, it looks complex, but if you have used it once, it is easy. I use several of these counters in my equipment without having any difficulties with reading the frequency. For some examples see the pictures below. The picture here above is the counter I am using in my general coverage receiver, it has the MHz / kHz switch and displays 8.2 MHz. All the others have only the kHz display as they are built for the CW parts of the ham bands.

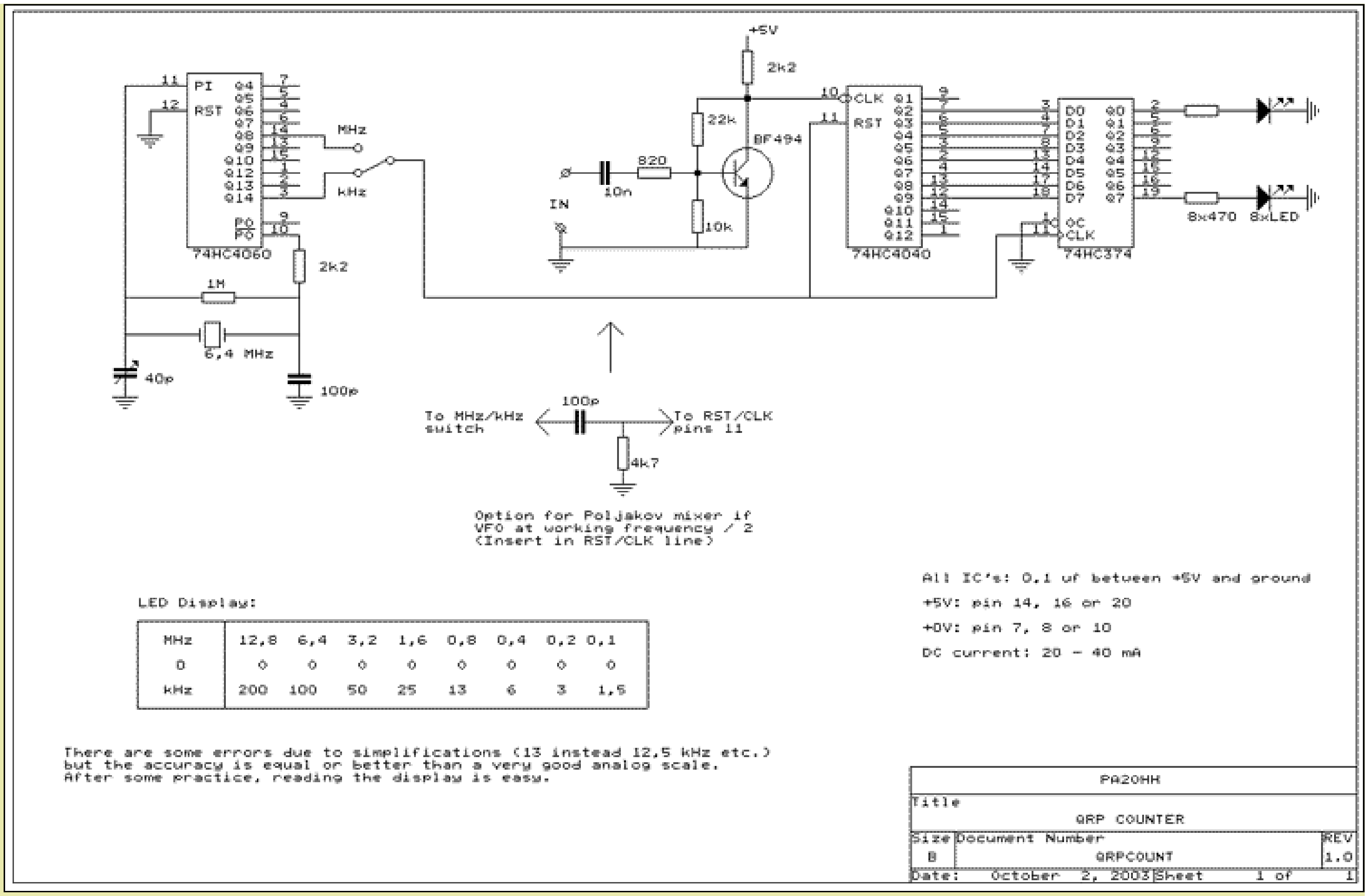
Working principle
The 74HC4060 oscillator with the 6.4 MHz X-tal generates a frequency of 390.625Hz in the kHz position of the switch and 25 kHz in the MHz position. Only half the period is used for counting. During the +5V half period, the 74HC4040 is reset. As soon as the clock pulse goes to zero, the 74HC4040 starts counting the pulses from the BF494 preamplifier until the clock pulse rises again to +5V. Then it is reset again. But just before the reset, the actual count value is latched in the 74HC374, that also drives the output leds.
And that is all...

Modification for cases where the VFO works at half the working frequency
Sometimes a Poljakov diode mixer is used in direct conversion receivers. With such a mixer, the VFO oscillates at half the reception frequency.
In those cases, add an RC network (100 pF / 4k7) in the CLK/RST line to the pins 11 of the IC's. The RST/CLK pulse is now only a very short needle puls instead of half a period of the 390.625 Hz signal and the counting period is doubled (minus the very short almost negiglible RST/CLK pulse). As the counting period is doubled, the frequency read out is correct when the VFO oscillates at half the working frequency.
If necessary, the error caused by the short RST/CLK pulse can be corrected by re-adjustment of the 40 pF trimmer (adjust the frequency of the crystal oscillator a little lower than 6.4 MHz).
However, for the MHz position, you will have a considerable error as the reset pulse is quite long compared with the short gate pulse in the MHz position.

Sensitivity

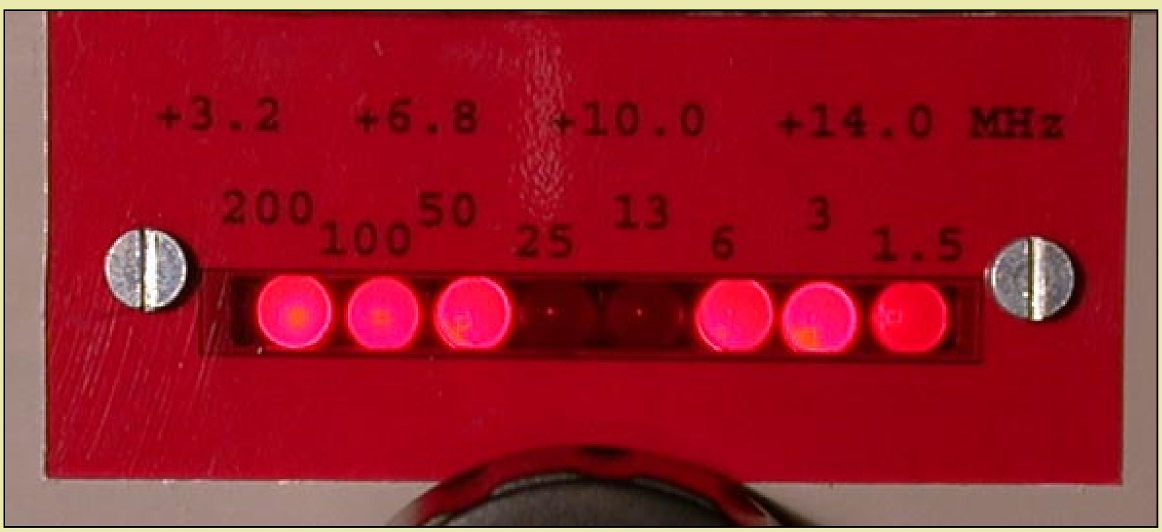
Frequency (MHz)	Sensitivity (mV rms)
0.1	150
0.3	50
1	15
3	8
10	15
30	130
50	?

Notes
You should build the counter in a screened box to avoid RF interference in your receiver!!

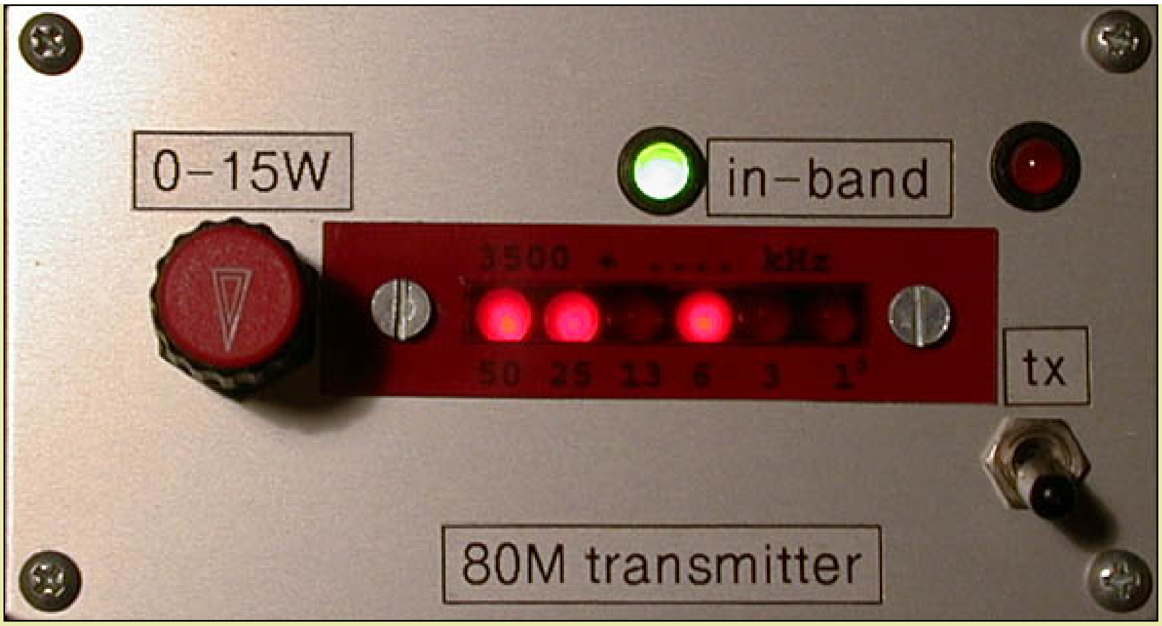


Circuit diagram

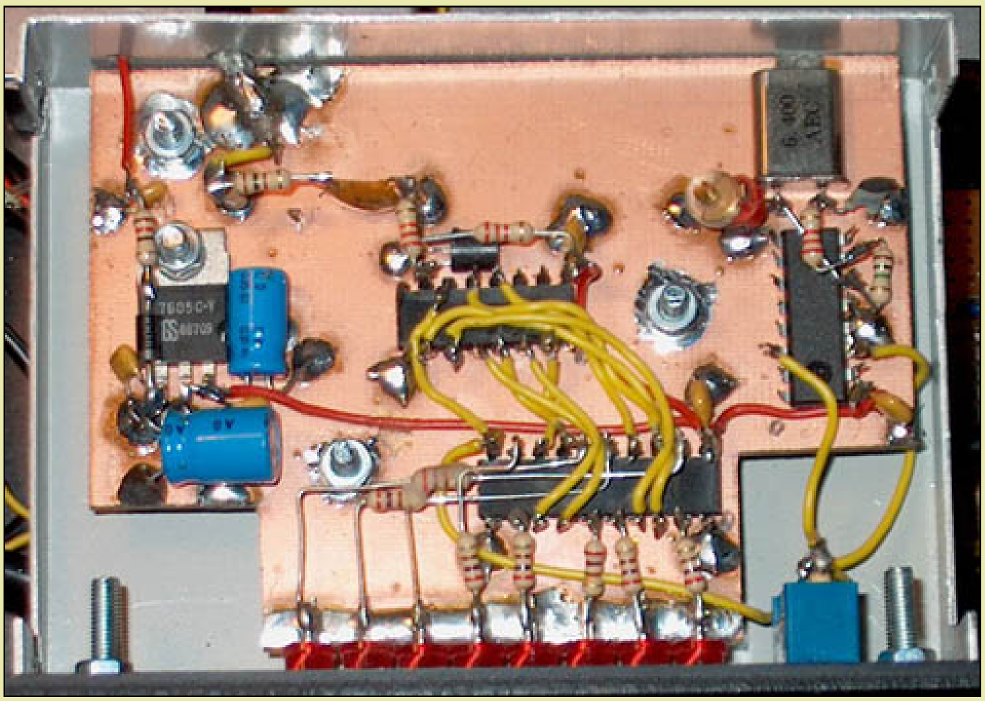
[big diagram]



In my 80-40-30-20 M CW transceiver (3560,5 kHz)



3581 kHz, led D7 is not used, green led D6 is the in-band led (3500-3600 kHz)



Inside one of the counters

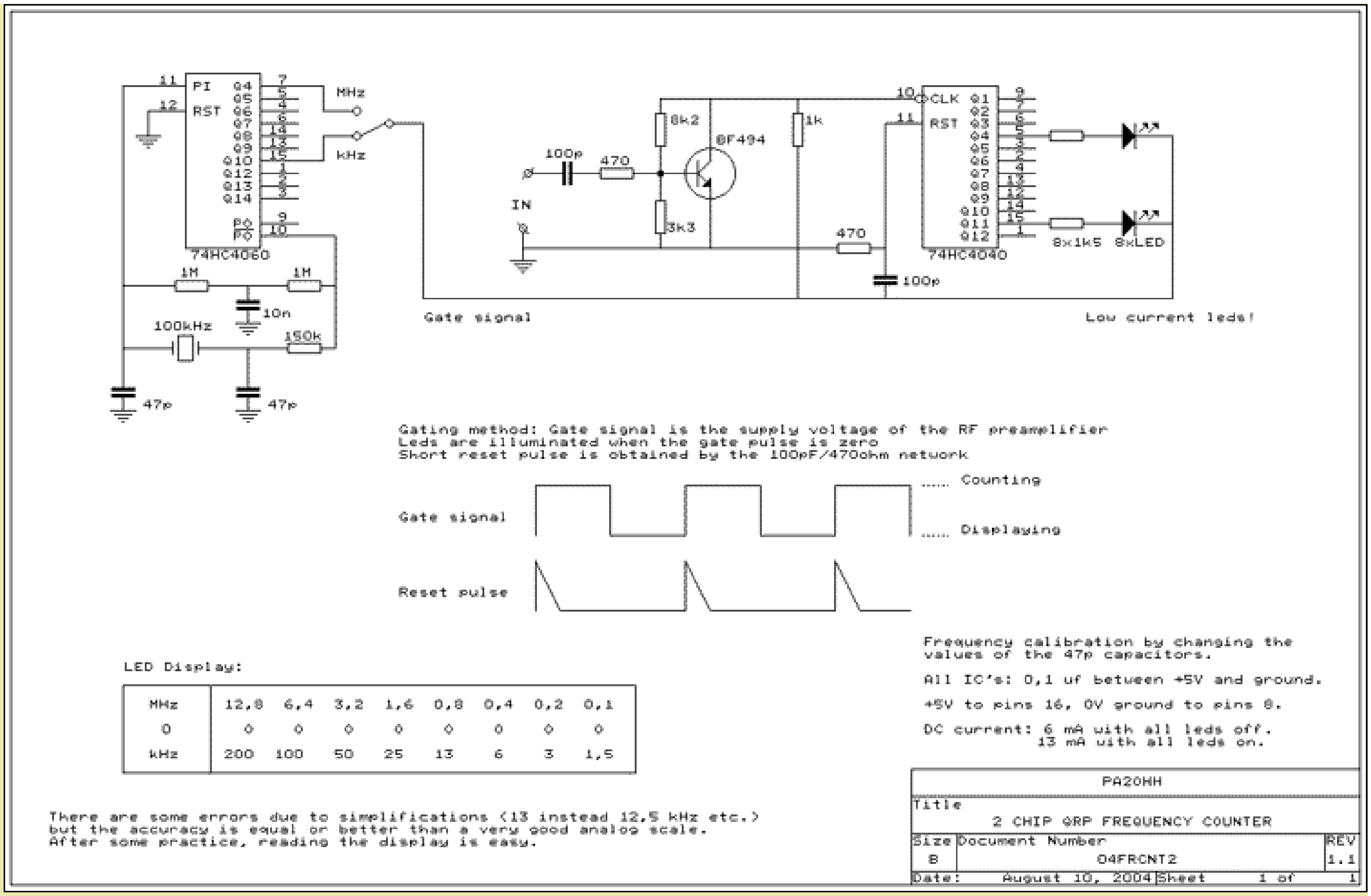
FROM 3 TO 2 CHIPS!

(2004)

The little 2 chip version with 3mm low current leds.
Much more accurate than the old dial!

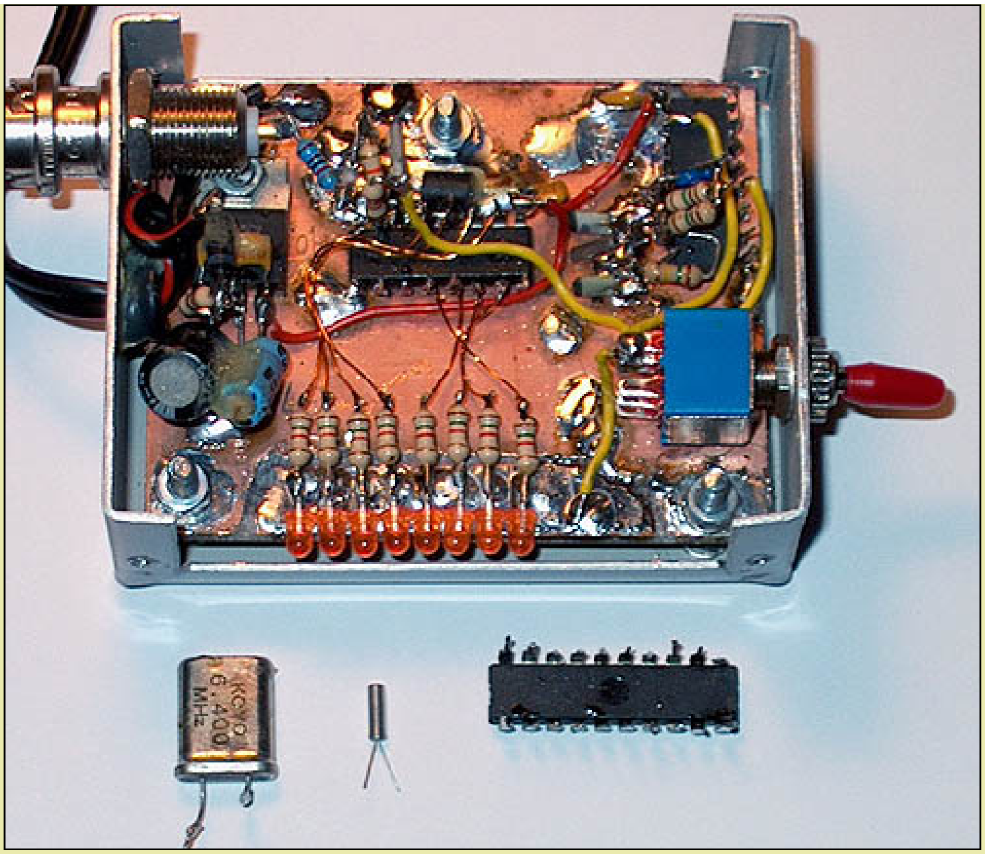
Further simplified!
This idea came from Hans Summers, G0UPL. He also has a very nice and interesting website, http://www.HansSummers.com.
Hans made a very nice counter with a 0.5 to 100 kHz 8 leds display, very small, very low current and even without the led resistors. So do not forget to visit his website!

It is possible to connect the leds directly to the 74HC4040 and delete the 74HC374. It works as follows: We reset the 74HC4040, then count, then stop counting and display the frequency and then reset again etc. However we need a gating mechanism for the input signal for that. And for that gating we need again a 3rd chip! But Hans had a solution for that: Do not use a chip but a simple device like a diode that is switched on and off! Here is chosen for switching the supply voltage of the RF preamplifier. The input signal is only fed to the 74HC4040 when the RF preamplifier is supplied by the +5V of the gating signal. During the 0V period, the RF preamplifier is switched off and the 74HC4040 stops counting. The outputs do not change anymore and the leds are illuminated. The leds on their turn are only illuminated if the gating signal is zero and are off when the 74HC4040 is counting (gating signal +5V). At the beginning of the counting period, the 74HC4040 is reset by the short reset pulse from the 100 pF/470 ohm differential network.



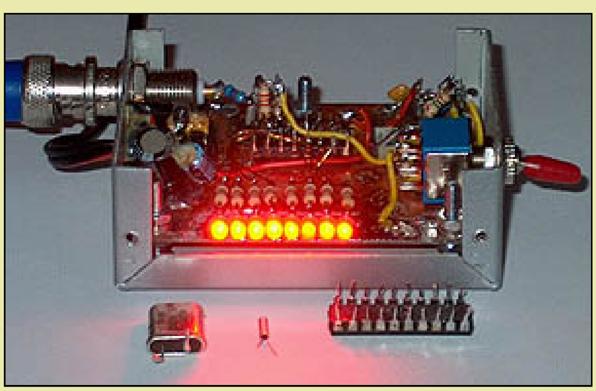
Circuit diagram
big diagram

Very suitable for Battery operated QRP equipment.
This frequency counter is very suitable for battery operated QRP equipment due to the minimum number of components and the low supply current of 5 to 12 mA. There are some disadvantages compared with the original 3 chip version but there are solutions for that.



The prototype of the 2 chip frequency counter and the deleted 74HC374.
Compare the size of the small 100 kHz crystal with the 6.4 MHz one!

100 kHz crystal instead of a 6.4 MHz one.
The gating time is shortened with the length of the reset pulse and/or the settling time of the RF preamplifier. Therefore, the input capacitor of 100 pF should be as small as possible. It gives an error in the kHz position that can be corrected with tuning the frequency of the crystal oscillator a little lower. However, in the MHz position this error is too big, especially at 30 MHz.
But there is a solution for that: Increase the length of the gate pulse. The reset pulse to gate pulse ratio will be smaller, resulting in a smaller error. However, the gate pulse cannot be too long, the leds start flickering when the frequency of the gate signal is too low.
Increasing the length of the gate pulse cannot be realized with the 6.4 MHz crystal as Q14 is the connection with the lowest frequency. Therefore, the 6.4 MHz crystal is replaced by a 100 kHz crystal. Another advantage is that it is much smaller than a 6.4 MHz crystal, see the photograph. The gate pulse is 4x longer than in the 3 chip version.
The oscillator circuit also had to be modified. The 2k2 resistor is increased to 150 - 270k ohm and the 1M resistor is replaced by two resistors of 1M ohm and a decoupling capacitor.
Other resistor values are chosen in the RF transistor amplifier to shorten the settling time.



Despite the high serial resistors, the low-current leds are bright enough!

Low current leds.
During counting, the leds are loading the outputs of the 74HC4040 and also the gating signal. In the 3 chip version, the leds are on for 100% of the time, here for 50% and for the other 50% the RF counting pulses of the 74HC4040 are present on the leds. This can generate some extra RF interference.
The low current led are used to keep this RF interference and the supply current to a minimum. Also the loading of the counter during counting will be kept to a minimum due to the 1500 ohm serial resistors instead of the 270-470 ohm as used in the 3 chip version.
The leds are not connected to ground anymore and have to be mounted on an isolated strip connected to the gating signal.

On off switch.
The RF preamplifier is switched on and off by the gating signal. Due to the varying load, this may cause variations of the VFO frequency in the rhythm of the gating signal. A solution is a buffer amplifier or an on/off switch! Switch on the frequency counter only when you want to read the frequency. Also the generated RF interference is not a problem anymore! And it will also decrease the average current to less than 1% or less than 100 uA!

Sensitivity and accuracy.
The displayed frequency is a little dependent on the input level of the signal. This is caused by the settling time of the RF amplifier. It is the price we have to pay for deleting one chip...
The following values were displayed as exactly 30 MHz:
100 mV: 30.0016 MHz
300 mV: 30.0009 MHz
1000 mV: 29.9999 MHz

The following values were displayed as exactly 10 MHz:
30 mV: 10.0006 MHz
100 mV: 10.0003 MHz
300 mV: 10.0000 MHz

In the MHz position, the difference at 30 MHz was 20 to 70 kHz, but this is not important. The MHz position is only used to find the approximate frequency.

Frequency (MHz)	Sensitivity (mV rms)
0.1	500
0.3	200
1	50
3	30
10	30
30	100
50	200
60	300
80	500
100	1000

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